WL-TR-97-8053

AGILITY MEASURES: ENGINEERING AGILE SYSTEMS

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February 1997

FINAL REPORT FOR THE PERIOD 01/20/95 - 05/31/97

Approved for public release; distribution unlimited

MANUFACTURING TECHNOLOGY DIRECTORATE
WRIGHT LABORATORY
AIR FORCE MATERIEL COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433-7734

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This technical report has been reviewed and is approved for publication.

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REPORT DOCUMENTATION PAGE

FORM APPROVED
OMB NO. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*

2. REPORT DATE
February 1997

3. REPORT TYPE AND DATES COVERED
Final 01/20/95 - 05/31/97

4. TITLE AND SUBTITLE
Agility Measures: Engineering Agile Systems

5. FUNDING NUMBERS
C F33615-95-C-5513
PE 63570E
PR A934
TA 00
WU 02

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Sirius-Beta
1976 Munden Point Road
Virginia Beach, VA 23457-1227

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Manufacturing Technology Directorate
Wright Laboratory, Air Force Materiel Command
Wright-Patterson AFB OH 45433-7734
POC: C pt Paul Bentley, USAF, WL/MTIM, 937-255-7371

10. SPONSORING/MONITORING AGENCY REP NUMBER
WL-TR-97-8053

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for Public Release; Distribution is Unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT

This report is the product of work sponsored by the Defense Advanced Research Projects Agency (DARPA) and managed by the U.S. Air Force's Manufacturing Technology Directorate. The objective of this project was to discover, understand and usefully describe formal, quantitative-based metrics associated with agility in the virtual enterprise. These metrics are of the type that managers can use in making decisions.

14. SUBJECT TERMS
Manufacturing & Industrial Engineering & Control of Production Systems.

15. NUMBER OF PAGES
406

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASS OF THIS PAGE.	19. SECURITY CLASS OF ABSTRACT	20. LIMITATION ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z239-18
298-102

Readers' Guide

This section contains some reader hints and several suggested reader roadmaps.

The metrics project was an ambitious project, so it is no surprise that this report is an ambitious document. There is more than one *idea* reported here for the first time, more than a few controversial *issues* are touched upon, many disciplines are invoked, and solutions presented depend on difficult ideas.

Early in the project, we struggled with how best to present our results. Like agility, the insights are systemic, they may be interesting individually, but they gain greater power when linked together. Our problem as we knew it: we needed to produce one document, but we knew we had widely differing purposes and several distinct types of readership.

So what we've done is create a hypertext document. Instead of just being a digitized report, we authored it to take advantage of the hypertext medium's strength to allow a reader to set their own linear path. We provide several aids to assist that navigation:

- Many hyperlinks. There are a few thousand links in the text. Usually, they take the reader to a place where more detail on the topic is given. We've been judicious in how these are used and placed them only where we think the user will trigger them. For example, the term AVE Focus Group is used and tagged frequently. But we think that tagging *every* instance is distracting. So we tag it when we think more information *might* be desired.
- We've made each narrative self-contained as much as we could. This has resulted in some redundancy. We felt that readers should not *have* to jump around merely to follow what's going on. In each case, there is one detailed discussion to which one can jump from the watered down summaries placed in certain discussions in order to preserve the flow.

  The philosophy of self-contained narratives has forced us away from using acronyms in almost all cases unless defined immediately before. This is a boon to any reader we think. The only exceptions are AVE and VE which are so common that if they were spelled out, the long form would be distracting.
- We've provided several textual aids:
  - An annotated Table of Content which will probably serve as the basic map for most readers.
  - A good Index which will help those looking for coverage of specific topics.
  - An abstract at the beginning of each section which provides a hot-linked overview of that part. All of these abstracts are reproduced below.
  - A few reader guides, later on in this preface. These are provided as an overview for people with agendas that do not map well to the report's four divisions. We give an example-based roadmap and a contract

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reviewer's roadmap.

- We expect to have four specific types of readers, so have structured the report to contain four main parts. These sections inter-relate:
  - Part 1: This is for someone who just wants the useful results of the project: what tools resulted and how do they work (with an example). The first section of this part serves as a self contained executive summary of the metrics only.
  - Part 2: Some critical readers will want to know the underlying definitions and associated issues as well as how this project relates to others. Part 2 is for them.
  - Part 3: A major result of the project has bearing above and beyond the metrics: how to rigorously deal with social and cultural issues. This major thread deserved its own part. Many examples are packed into this thread.
  - Part 4: One goal of the project is to transfer the method and associated technology. This part is the most technical of the four, giving those details, which also includes a related case study.
- We've studied numerous sites and have concluded that the best browser experiences are when the pages load fast, fast, fast. So we've tailored the document to have small sections. Dependence on graphics in order to understand the point is kept to a minimum. In the HTML version the sections are small and the graphics are black and white gifs (except for screen shots). Nearly everything in this document has been beta-tested for both content and electronic *form*; this is several generations advanced from our early format, based on feedback from our web site.

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Readers' Guide

1 Reader Guides

1.1 Abstracts of Parts

What we give here are identical copies of the abstracts contained in each part

1.1.1 Abstract of Part 1

Part 1 is for readers who simply want a users' view of the metrics and how they work.

We provide an executive overview of the metrics with an example. Details on the approach are given, first the Reference Model which is central to the first step. In describing the model, we review some case studies we used in calibrating the model. A review of the second central element of the process, communicative act modeling is given in some detail.

Finally, we introduce a process not central to the metrics, concerned with strategic brainstorming for agility. We devised this method because apparently none existed.

1.1.2 Abstract of Part 2

Part 2 is targeted toward the reader who is interested in *indepth* discussion of issues which surrounded the project.

In this part are collected a number of results on which were incidentally reached. There are a few examples given: agility as competitive weapon, and extremely dynamic market forces. The benefits to the U. S. economy and the defense base are reviewed.

Projects which lead up to the metrics project are summarized, as well as technical efforts which contributed to success of the effort. An exhaustive examination of definitions is given: The virtual enterprise, the agile virtual enterprise, and many issues related to metric.

We compare agility to many other efforts which benefit an enterprise, and other sponsored agility research. A short summary of the approach is recounted and known limits are reviewed.

1.1.3 Abstract of Part 3

Part 3 is for the reader who is interested in social and cultural issues and what we've done about them. Many examples are in this part.

We begin this part by recounting an extensive example beginning in the whaling industry and ending with agile movie production processes. We continue with a specific movie case, software coding, Russian entrepreneurs, and virtual car manufacturing.

Cultural agents are introduced, and some background issues discussed. Trust, trust agents and trust metrics are defined.

We review French and English history to extract key insights into defense engineering practices. Then we tie it back to the movie example with a case of trusted agents using lightweight contracts and unifying themes. And the whole affair is tied back to the defense case. The case for defense support is made.

We then turn to the specific approaches to soft mathematics. Situation theory is introduced and explained.

We report on our activity in setting up a workshop, report results of that workshop, and detail future action we plan.

1.1.4 Abstract of Part 4

Part 4 is for those who need more detail about the defense case and how to develop tools. It is a little more technical.

In order to set the stage for a case study, a specific missile problem is noted. We note the difference in the defense legal system and explain it historically. Using these insights, an ideal defense supply chain is proposed.

After giving, in detail, a scenario we studied then set aside, we set up the case study scenario. The questionnaire we used is reproduced. Then the results are reported. Within the case study, we had occasion to consider how we would work with methods of consultants; how we would integrate with a representative system is reported.

We then turn to tools whose need was indicated in the study. Several tools are described. One of these tools, the one most immediately needed has been prototyped. It's internal structure is given in detail. That tool automates an algorithm which is central to the metrics. The algorithm is outlined here.

In terms of future tool actions, we mention our own special strength we bring to future toolsets and outline how we will integrate with other projects.

1.2 For the Example-Oriented Reader

When we started the project, we made a deliberate decision to be rigorous in our work. So many writings from others, not only in the agility space, but the whole area of enterprise technology seemed superficial. A characteristic is to provide some anecdote, generalize and move on. In eschewing superficiality we decided to keep this report empty of examples.

We were quickly disabused of that notion. Not only is it true that the closest way to comprehension is through example, but also that we had to show how some of our notions work in real life. Moreover, as the work progressed, we were presented with such interesting stories, such compelling cases that we couldn't contain ourselves.

No danger of that; our support group *demanded* the examples, many needing them to support just the same rigorous thinking we wanted. A note about our examples. In no case will you find these examples anywhere else in this form. These

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are not remote observations, common to the management press; each case was discovered and analyzed specifically for the project and this report.

Most sources are proprietary, which is a nuisance for sure, and some cases are noted as an anonymous company. But our experience on prior projects have convinced us that this is the best way to get fresh, real information out. We give some public sources for background on the cases in the bibliography, for those who want to examine them more closely.

In particular, the sweeping, multidimensional movie/whaling/law example is based on heavily proprietary insights.

1.2.1 Example Reader's Guide

There is a wideranging case study which appears throughout the report. It covers a couple hundred years, ending in a specific defense manufacturing example, the ideal and the real situation.

It begins with the U. S. whaling industry as an example of a virtual enterprise, how it had an agile response to the gold rush, and again to the discovery of petroleum. We track how much of the cultural and legal infrastructure from the oil industry was inherited from the whaling industry and passed to the movie business.

The movie business is examined more closely. We follow how its cultural and legal infrastructures were used as an example by the Japanese in their engineering of enterprise infrastructure after the war. Then a major improvement, the packet unit system was introduced to movie production by wartime research sponsored by the predecessor of the Air Force Manufacturing Technology Directorate, motivated by success in the Panama Canal.

This flourished and became the focus of second-generation attention by the Japanese as a model for more agile enterprise engineering technology. The centerpiece of that, the use of high concept descriptors to supplement agile assembly of virtual enterprises is examined, and we give a case where a Japanese firm learned a hard lesson.

We look at how an ideal defense aerospace supply chain would look if it followed these principles, and assume that to be a strategy for a typical missile prime. We further assume that the missile prime is addressing a very real defense vulnerability which likely will result in combat losses, not because of a lack of funding or technology, but because the supplier base is unagile.

We look closely at a real defense prime to see how much it would cost to collect the information required to use the metrics to reengineer the supply chain with the ideal in mind, and find the cost in line with reengineering of similar ambition. A subset of that example is used to illustrate the executive summary. Along the way, we look at a representative reengineering methodology to check how easily the metrics can be integrated. (Elsewhere, we do the same for integrating the metrics into other sponsored agility projects.)

Incidentally, we examine other examples:

- A railroad which has a novel strategy of creating virtual enterprises to develop

its customer base.

- A bidding consortium which represent many small firms as if they were one.
- An aerospace prime who invests in codifying knowledge for transfer to partners of convenience.
- A consumer electronics prime which has an innovative way of evaluating the possible liabilities carried by potential suppliers.
- A defense electronics prime which engages suppliers in strategic new product definition.
- An airline that invests a supplier with highly proprietary knowledge though that supplier is tightly coupled to the airline's competitors.
- A shipyard that engages its defense suppliers to manufacture a commercial process plan as if it were a physical product.
- A software house, itself a virtual enterprise, which uses a novel risk reward strategy to produce companywide agility.
- A revisiting of many of the above two years later to show how agility they had failed to help when the agility need was unplanned for.
- How the workprocessing business changed hands.
- How the electronic game device business changed hands.
- How control over broadcast electronics changed hands.
- Where agility was used as competitive weapon in the automotive industry.
- Where agility was similarly, and more massively, employed as a weapon in the fast food business.
- Where Israeli defense acquisition planners used agility to address a missile threat.
- Where earlier, Soviet launch vehicle managers did the same thing, and how the technique has penetrated the new Russian entrepreneurs.
- Why agility is found in Indian software collectives as a cultural effect.
- Why a major automotive virtual enterprise in the U. S. failed for cultural reasons.
- Why a major semiconductor virtual enterprise in the U. S. failed for different cultural reasons.
- What benefits certain behind the scenes associations see in agility.
- What benefits the investment community sees in agility.
- How trust is culturally based.

We hope you enjoy these examples. None of them were developed as much as we would like, or even described here as much as they were developed. If we had, their role in supporting and illustrating the novel contribution to metrics would have been compromised.

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1.3 For the Contract Reader

This report is the product of work sponsored by the U. S. Department of Defense. The funder is the Defense Advanced Research Projects Agency (DARPA) and the manager is the Manufacturing Technology Directorate of the Air Force Wright Laboratories (ManTech). The overall program of which this is a part is the DARPA/NSF Agile Manufacturing Program, which involves many sponsored efforts. The contact number is F33615-95-C-5513, being a successful response to Broad Area Announcement 94-31.

The contract requires a specific structure for a final report (CDRL A001), which is addressed in this section.

1.3.1 The Problem Addressed During this Effort

Agility is a new concept which, because it is new, is difficult to grasp, albeit easy to define. As a result, many researchers have fallen back on older concepts, and existing tools under the rubric of *Agility*. In any case, the majority of work has been either:

- a revisiting of existing tools and technologies under the belief that if they were only done better, agility would result or be improved
- a consolidating of thoughts into very high level guidelines, themes and rules of thumb that are speculated to support one of the definitions of agility. Generally, these guidelines are used for motivational purposes.

While these efforts may be useful, they still do not satisfy the key questions that must be addressed in order for managers to be able to engineer the ability to respond to change into a diversified enterprise.

We need to know how to evaluate the threat, how to determine whether process or partner is agile, whether it is sufficiently so (to address the threat) and what the relative costs will be. We need quantitative, objective metrics that speak directly to an *engineering* analysis of the enterprise. We need a foundation for balancing the costs of agility against its benefits.

The Defense Industrial Base is clearly in need of re-engineering. Some of the problems, including a major one we've identified, are a result of a non-agile supplier base. If agility is to be engineered into a supplier base for a weapon system or class of weapon systems, then engineering tools need to be developed, and metrics are the first step on such development.

We know that such engineering tools will not flourish in the defense base unless they are enthusiastically supported in the civil sector. We also believe that rigorous foundations are essential, but integration with many intuitive tools and methods must be effected in order for the metrics to be useful.

So we addressed the creation of formal metrics for pure agility that can be used by civil and defense sectors, and easily integrated into many tools and methods for diverse users. We used the Defense Agile Virtual Manufacturing Enterprise as the most difficult case.

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1.3.2 The Work Performed Under this Effort

We knew that the project was ambitious: we had been the government's agent on a multibillion dollar attempt at the same target which had failed. But we believed that we could align a number of parallel trends, prior results, and new players to quickly synthesize some high value results.

- We devised formally-based agility metrics that can be inserted into, interfaced to, integrated within or accessed by a wide number of important tools and methods by a spectrum of users.
- We mobilized a review panel that involved over a hundred persons which met dozens of times. We conducted a wider review by a dedicated email list, and a web site which involved thousands of interactions.
- We conducted a sweeping case study that followed the evolution of legal infrastructure resulting in a defense base problem. This large effort, which involved the movie business, was partially subsidized by a large consulting firm. This case study evolved into a close look at a specific coupling of an example consulting group and a defense aerospace prime to determine the cost of applying the metrics. While costly, the process compares to similar strategic modeling tasks. The first chapter of the case study was published by the Agility Forum and as been widely quoted in business media.
- We conducted a dozen individual case studies to develop and validated the AVE Reference Model.
- We spun off an independent activity to address advanced soft issues, primarily the engineering of social and cultural dynamics. This spinoff was cofunded with industry and has set the foundation for promising, perhaps revolutionary work that has already resulted in two books [DEVL97] [DR96].
- We clearly and publicly described the key algorithm and object implementation strategy so that tool suppliers could see what is going on and tool builders can evaluate instancing the metrics. We've also outlined examples, and in some cases prototyped tools that would employ the metrics. These are downloadable from the web site.
- We've been remarkably successful in communicating the results through the physical and virtual meetings noted above. These have been supplemented by dozens of private presentations to commercial sites, and numerous professional conferences.

1.3.3 Relevant Test Results

We supported two different types of tests:

- Continuous testing of the ideas in the project by AVE Focus Group (and its electronic siblings) by close examination of a dozen or so case studies.
- A single, focused instance of a missile prime and a (for our purposes) representative consultant, which formed part of our major multi-industry case study. The purpose was to determine whether the cost of modeling for strategic agility was

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greater than similar modeling to support strategic planning.

1.3.4 Program Benefits

We believe that we now have workable metrics and a tool strategy that can be used to engineer agile supply chains in specific industries where the changerate is high. These can be applied in a future phase on emerging defense aerospace systems.

1.3.5 Implementation Benefits

1.3.5.1 Generalizations

We have presented the statement of the *problem* and the *solution* in a variety of ways for different constituencies. We have identified four major groups which correspond to the four sections of this document. All indications are that we have succeeded in our goal of speaking to tool builders and strategic planners in both the civil and defense sectors.

But there is a group that will be outside our reach. We have determined that there are large segments of the economy for whom agility is neither a concern nor should it be (A), and this includes important parts of the defense industrial base. However, electronics and aerospace systems, especially complex systems are likely candidates for agility.

1.3.5.2 Implementation Schedule

We plan to follow through in making the metrics widespread. Some methods and strategies will be given away, others licensed. We also plan to bring to products, the tools outlined in Part 4.

1.3.5.3 The Contractor's Toolbox

Our *statement of work* doesn't call for a specific implementation. But we've accelerated an implementation strategy beyond what we planned. Although the effort was unrealistically ambitious, we were able to leverage other efforts and obtain industry cofunding. So we were able to prototype our primary suggested tool instead of merely specifying it.

1.3.5.4 Target Industries

It is clear from our industry advisors that only large primes have the luxury of engineering supply chains, and this is true of engineering agility as well. We have also found that only a portion of industry will be concerned with agility because their changerate is low.

Clearly aircraft and missile projects are targets for the results of this research, and we expect to pursue solving some problems in this sector.

As noted in Part 2, non-U. S. firms, especially in emerging economies are very interested in both agility and the metrics. This appears to be because they have less legacy that is immutable. They are building whole new industries from scratch. For instance, we were visited by a Chinese delegation chartered with establishing a major domestic aircraft industry, and they wanted to be more agile than Boeing and AirBus.

1.3.5.5 Relevant Conferences

We have found that the web site is the most powerful way of publishing. It gets an average of 4,000 hits a month. We expect that to greatly increase as new material appears. We've described in some detail communities which we've leveraged, and how we'll continue to leverage them.

We've published the first part of the case study as a report by the Agility Forum, and will have the executive summary of Part 1 published in Agility and Global Competition. We've been asked to write our results in the new Springer Verlag International Handbook on Information Systems, and have an article in the forthcoming BioSystems.

The metrics have become involved in the Series of meetings by the Foundations of Information Science, the International Society for the Interdisciplinary Study of Symmetry, and the International Society for Group Theoretic Cognitive Representation and International Conference on Enterprise Integration Modeling Technology.

We've presented in three Agility Conferences, three BAST Conferences, the National Virtual Corporation Conference and the National Business Process Re-engineering Conference in addition to meetings of the societies noted above. These have been useful, but we think that the most powerful strategy is web publication balanced with concentrated site visits.

1.3.6 Summary

We realized that the agenda was ambitious and could only be addressed by the effort of a large coordinated interdisciplinary group. So that is the approach we took. We spend substantial effort in facilitating multiple parallel focused efforts. Some of these were electronically based.

By these, and a few special subprojects funded or cofunded by others, we were successful in leveraging the government's investment manifold.

In terms of results, we have achieved the definition and validation of formally based quantitative metrics to evaluate engineering. We've described, and posted on the web, several ways that these metrics can be used in different methods, tools and research thrusts.

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We also have produced two unexpected products which have assumed high importance. With Sandia, Automation and Robotics Research Institute and the AVE Focus Group, we have developed a structured controversy method for brainstorming agile strategies and alternatives.

Also we have instigated with Steelcase, Automation and Robotics Research Institute and Industrial Technology Institute a major effort in Soft Modeling: a new approach to modeling the unknown and social/cultural dynamics.

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[We decided it wasn't appropriate.]

Part 1, Metrics Handbook

[Part 1 is for readers who simply want a users' view of the metrics and how they work.]

2 Abstract

We provide an executive overview of the metrics with an example. Details on the approach are given, first the Reference Model which is central to the first step. In describing the model, we review some case studies we used in calibrating the model. A review of the second central element of the process, communicative act modeling is given in some detail.

Finally, we introduce a process not central to the metrics, concerned with strategic brainstorming for agility. We devised this method because apparently none existed.

3 Executive Overview

[A single chapter overview of the metrics with a simple example. This section is a standalone executive overview.]

Though general ideas about agility abound, precious few formal foundations for the new discipline of *engineering agile systems* have been available. At the root of this need is the lack of measures or metrics to evaluate quantitatively the agility of a process or business enterprise. Here, we present such metrics, together with suggested uses for building a discipline to engineer dynamic virtual enterprises.

3.1 The Problem

[A brief description of what is agility and why we'd want to measure it.]

Some managers claim that agility--the need to respond well to unexpected change--is a challenge they've been facing for decades; that it is nothing new. That's true, though the rate of change in general has increased. But in some industries, unpredictable change is now the premier characteristic: *surprise* permeates.

In others, for instance some defense sectors, the time it takes to develop a product is much longer than the generational life of key technologies and processes, and an inflexible system of maintaining the supply base works against you. Part 4 starts with an example where a lack of agility in the supply base is the primary impediment to producing a system to a long-standing threat.

As the need to deal with rapid change has increased, so has the potential for managers to engineer their business enterprises for change based on *knowledge* rather than instinct. *Responsiveness* is becoming recognized as a part of overall risk management and process engineering functions.

Instincts are unreliable in some market sectors. As social and technical clocks accelerate, the context can shift quickly; what worked yesterday may well not work today. In some games, the tolerance for mistakes, required for building the experience behind instincts, can ill be afforded. In any case, the management and investment community will always prefer reasoned decisions where a clear rationale based on metrics is applicable.

I've sat in on dozens of meetings where managers say they're convinced of the need for agility in their strategy, but that, once they get beyond the motivational speeches, they just don't know what to do. It's a plain fact that some of the better managers need agility and are ready to go, but they just don't have the tools for acting in an informed and decisive way. What they need is a sort of *black box* into which to put a process or a system of processes and get back a number measuring agility, which can be calibrated to the (time and) cost of change.

Change is old news, but the idea of carefully *engineering* an enterprise to thrive in change is new. In fact it's a radical idea--so radical that the agility community often hides this novelty rather than scare the meek. Nonetheless, it is a radical idea, one that requires new tools, some themselves also radical, and new types of decisions to add to conventional factors. At root, decisions are based on tools and

methods, and these are based on metrics. Without metrics, no one can make the decisions they need about the cost of agility versus its effectiveness.

Agility is like insurance; you buy it to counter a threat, to minimize a risk. Agility in one direction may not mean agility in another; in fact one kind could counter another. What kind and how much are questions that might be asked. A manager will also ask whether a given process or collection of processes contributes to an agile overall strategy, as well as what is the proper balance with other metrics (cost, time, quality of product) in a careful strategy.

So we must have metrics before agility can become a strategic factor in business planning. And it's likely that the problem will be difficult. The Defense Advanced Research Projects Agency (DARPA) sponsored us to work on this problem as a part of their Agile Manufacturing Initiative.

3.2 Leveraging Information Theory

[How some prior work measures complexity of computing algorithms, why we chose to leverage that basis.]

As a balance to the number of intuitive approaches to agility, we elected to work from the most formal applicable perspective. Most formal theories of systems which involve collaborative agents rely on *information theory*. The branches of this science which interest us have two roots: understanding the mechanics of language behind communication and characterizing the complexity of processes in computer programs.

We won't be overly technical in either this overview or the whole report. What's important is that a strong, well-understood mathematical discipline exists which deals with a formalized view of processes and their complexity. Computer scientists contribute to this mathematics because it is important to understand whether one algorithm will require more computer cycles than another, or more aptly, whether an algorithm can be used for many purposes other than its original context, and what would be the complexity of the program used to make the change.

Linguists have likewise contributed to this mathematical foundation. Among the many things not yet fully understood about language is exactly what, within the ground rules of languages, contributes to what elements of cooperation. It's a turbulent, controversial area, but at the core, some stable, useful mathematical ideas have been developed and exercised; these have been added to information theory.

Our strategy has been to take this formal knowledge and leverage it into the business domain to deal with our problem. This has been accomplished with some success because, while agility is a radical business idea, the mechanics of business are a simple subset of the larger world addressed by the original information theories.

Our business problem assumes that every participant in the enterprise is working toward a uniform goal (business success) that can be measured quantitatively in dollars, either *profit today* or *profit tomorrow*. We do not assume every process as measured locally contributes directly to this goal, but we do assume that each partner does so. (Also, we do not assume that every process is explicit and every

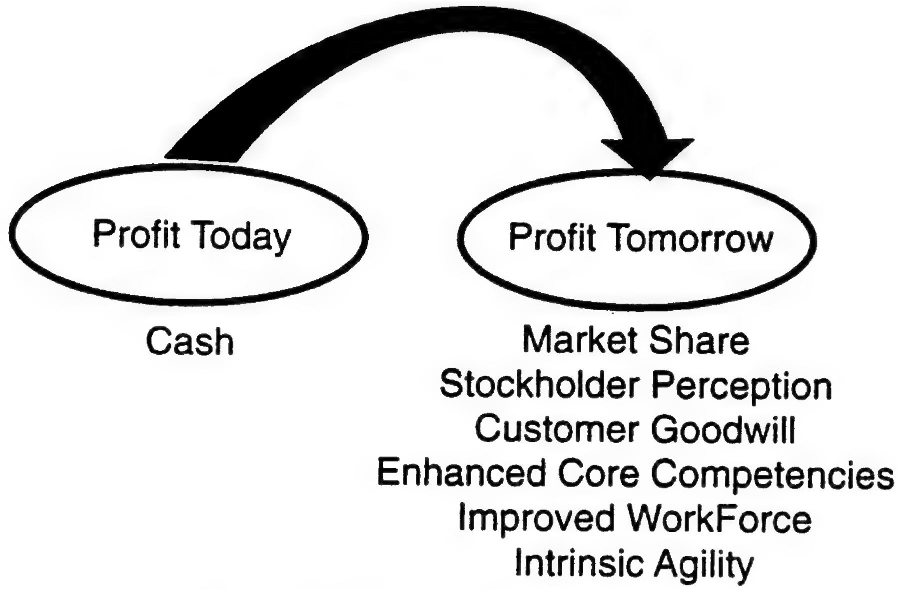

Figure 3-1:Strategic Considerations

relationship overt; we return to this below in our discussion of social and cultural dynamics.) Activities in the non-business world are substantially less well directed and behaved, so the business domain avoids most of the active unknowns and controversies among working information theorists.

A common view in this information world is to see only two main items: *agents* and the *communicative acts* that transpire among them, and many modeling meth-

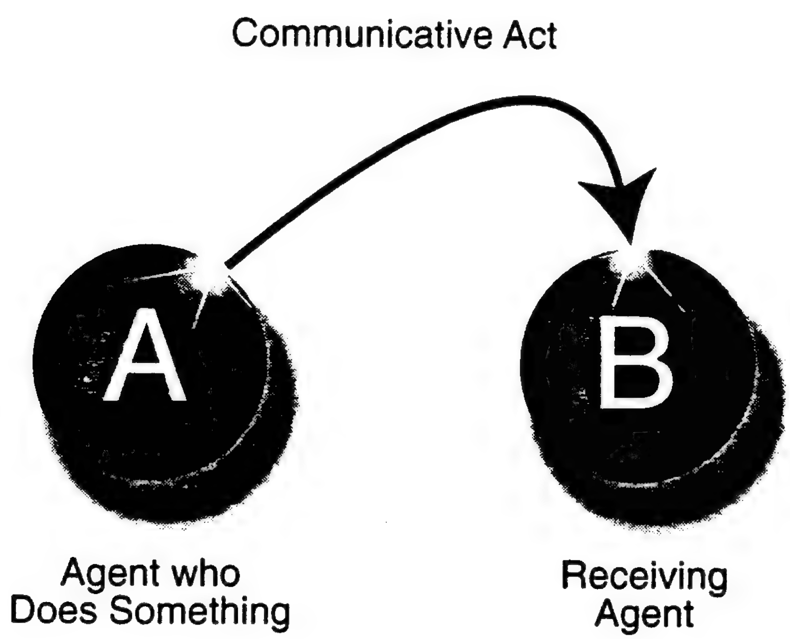

Figure 3-2:Acts and Actors

ods are based on this same simple breakdown. It can become quite complicated,

of course, as subtle distinctions and dynamics are added, but a simple version of this is the basic concept we use. For us, the world of communicative acts describes information-based collaboration.

In this information world, it is helpful if what each node does--what the communication is--is captured at the lowest level possible. We provide this by breaking each action into one of a few basic communicative acts. The taxonomy we use has been common for decades.

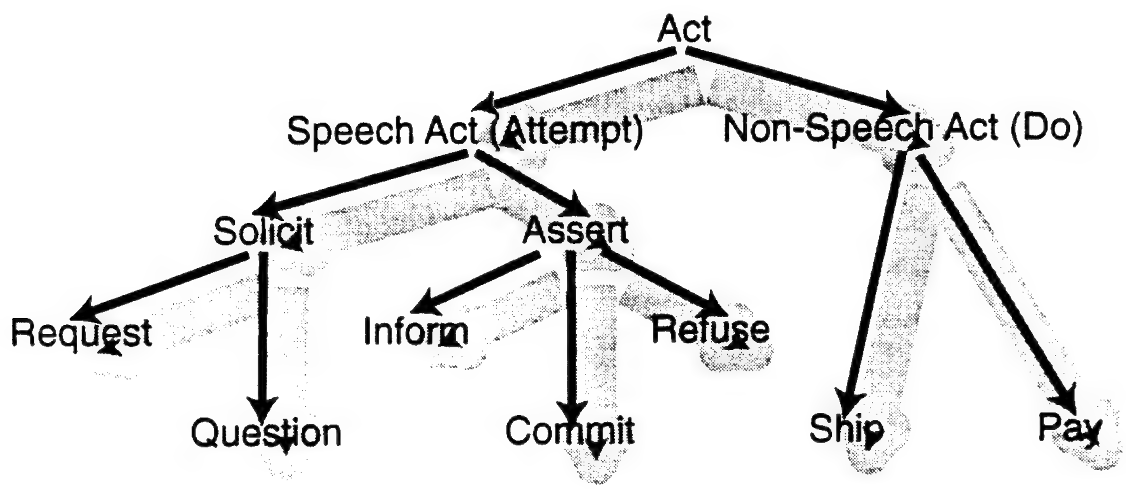

Figure 3-3:Communicative Act Taxonomy

Because our domain is business, we can get by with only a few non-speech acts. If we tried to measure the agility of, say, armed forces, we would need a more complex non-speech act breakdown than ship-and-pay.

Our metrics rely on a simple concept. If you take a business process and break it down into its agents and communications, the complexity of that representation correlates well with the cost of changing the process. And the relationship is well behaved arithmetically, so that resulting metrics can be considered with other metrics in strategic planning, risk management, and enterprise engineering tools.

3.3 Agility Metrics

[The core process of the metrics is outlined and a defense aerospace example is given.]

Our initial task was to find, among the various complexity features that information theory defines, a small number which have the following characteristics:

- They capture the various relevant notions of complexity that relate to dynamic adaptive coupling (agility)
- In doing so, they don't require unneeded, expensive-to-obtain information about the enterprise
- The number of features is minimal
- Each feature is independent of the others
- They are useful for the types of analyses business decisionmakers perform

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In mathematical words, the features of interest are complete, sparse and orthogonal, which characteristics make possible the useful mathematical operations that we need (including the arithmetic of accounting). We have found those complexity features which relate to agility. Combined, they provide a basis for that *black box* that business analysts and enterprise engineers need.

To describe them, we'll use the following example. The table shows a typical example process entered in a standard tabular form. Each row in the table denotes one of the standard communicative acts.

Sequence	Sender	Receiver	Utterance	Speech Act	Responds to	Replies to	Resolves	Completes
1	A	D	Might you have a need for N?	Question				
2	D	A	Now that you mention it, we might	Inform	1	1	1	
3	D	A	Tell me more	Question	1	1		
4	A	B	Do you have skillsets B', needed for N?	Question	2			
5	B	A	No, but we have B"	Inform	4	4	4	
6	B	A	Do you want us to develop B'?	Question	4	4		
7	A	C	If I do A' and B does B' or B", can we do N?	Question	2			
8	C	A	Yes; looks good; can do; only need B'	Inform	7	7	7	
9	A	B	We only need B'	Inform	6,8	6	6	
10	A	B	Can you commit to B'	Question	6	6		
11	B	A	We can commit	Inform	10	10	10	
12	A	C	Both A and B can commit to A' and B'	Inform	6,11	8		
13	C	D	Would you like us to address your need, N?	Question	12			

Table 3-1: Breakdown of an Example Process

The process modeled is a candidate case for delegated, distributed marketing by an Agile Virtual Enterprise's (AVE's) subordinate partners. Agents *A* and *B* are agents somewhere in the supply chain. *A* is a particularly astute monitor of a potential customer. Agent *C* is in the prime contractor, say a senior marketeer. Agent *D* is a potential buyer. This is a particularly promising process for agility, one which enfranchises a partner, even a minor one, to market a customer on the behalf of

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the AVE. It could be one of a few processes upon which this AVE could build an agility strategy.

In this scenario, *Acme Grinding (A)* finds a new need, *A New Jet Engine Thrust Nozzle Design (N)*, of which the customer, *Department of the Air Force (D)*, might not be fully aware. The AVE, which contains *A*, *B* and *C*, currently cannot meet the need. But it might if some processes change. Perhaps *Basic Casting Co. (B)* can satisfy part of the new need by developing a new process *B'*. Or maybe something less, a smaller change, *B"*, will do if *A* itself makes a change to *A'*. In both cases, it is unknown to *A* whether the prime, *Consolidated Aircraft (C)*, can fill in the other blanks, either by itself now, by changing, or by finding or changing other partners. So *A* has to do some discovery and present tentative results to the prime, *C*, for more discovery.

Perhaps Basic Casting makes nozzles of *nonamium* for Consolidated's new aircraft, which Acme cleans and treats. Consolidated and the Air Force selected nonamium over *newstuffium* because of the finishing costs. Acme learns of a new finishing process (*A'*) which might change that decision, and greatly reduce the cost of the aircraft, so much so that a competitor to Consolidated could (in the future) design a better, cheaper aircraft.

But Acme has to discover whether Basic can learn to make a clean newstuffium part (*B'*), or a more dirty part, using a less radical casting process *B"*. We've chosen this example because it assumes trust and novel reward strategies; these would be covered in another process which would be evaluated in a similar way. It also assumes that Acme can discover the cost of change within Basic, probably by using the metrics.

The table shows *A* going to *B* and finding out what *B* can do, then reporting the results of potential opportunity and capabilities to *C* for following up.

The Figure shows the same process in a specific graphical form, called a Dooley Graph, which reveals the structure of the communicative acts within the process. The conversion between table and graph is straightforward but sometimes unintuitive. The four columns on the right of the table are an aid in this process, which we will not detail here. (We've developed a little example tool, that we call Pomegranate, to perform the transformation automatically.)

Note in the Dooley Graph that some nodes are linked by lightly shaded links which are not communicative acts within the scope of the process. These are virtual acts, presumably supported by other processes or contexts in the enterprise. The number and type of such *virtual linkages* forms the basis for a related set of metrics we have developed, to measure trust. These are not discussed here.

There are two features of this graph which reveal its complexity; hence, those two are what we measure. They are complete, sparse and orthogonal, constituting a raw measure of agility. They are:

- *The number of nodes and the complexity of each node.* The complexity of a node is the number of other nodes to which it has a communicative link. Figure 3-5 tags the graph's nodes and links with these numbers. The node in the upper left,

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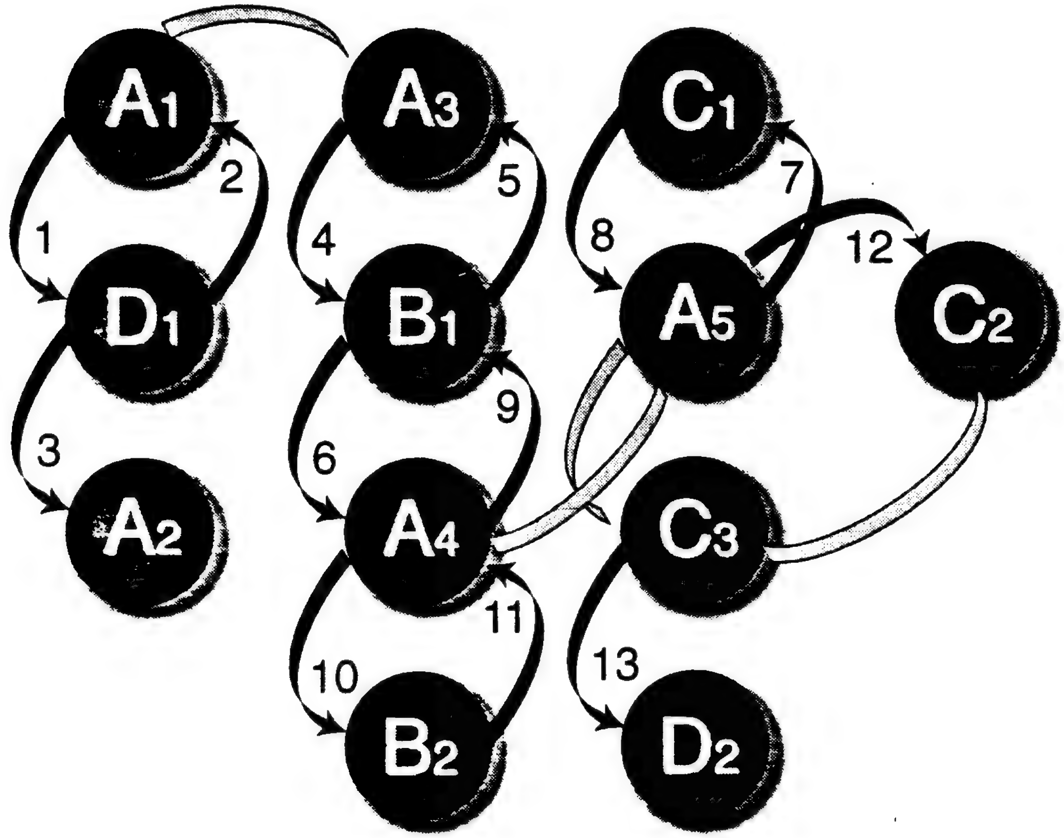

Figure 3-4:Dooley Graph of the Example

for instance, is a two-node, since it has two connections, even though they are to the same node.

The example has 12 nodes which break down into four nodes which connect to one other node, four which connect to two, two to three and two to four. The metric derived from this information is a simple sum of the number of each nodes raised to the power of its type. For instance, there are four two-nodes; since these are two-nodes, the four gets raised to the second power, 4^2 (it gets squared).

As a colloquial shorthand (providing a name rather than a formal definition), we call the sum the *Distance* metric. The example's distance metric is $4^1+4^2+2^3+2^4=44$. The first number records that there are 4 nodes from Figure 5 that are labeled 1; they have only one link associated with them. The number of linkages is also the power to which the count is raised, in this case, one. There are four labeled two, so that produces our second term, four raised to the second power. Two of the disks have three links, and two have four links, which gives our third and fourth terms of 2^3 and 2^4.

The higher the number, the higher the cost and/or time of changing the process. One can see this intuitively: the more *actors* involved, and the more each one does, the harder it will be to change the process.

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- *The number and complexity of links, or loops within the process.* A strict applica-

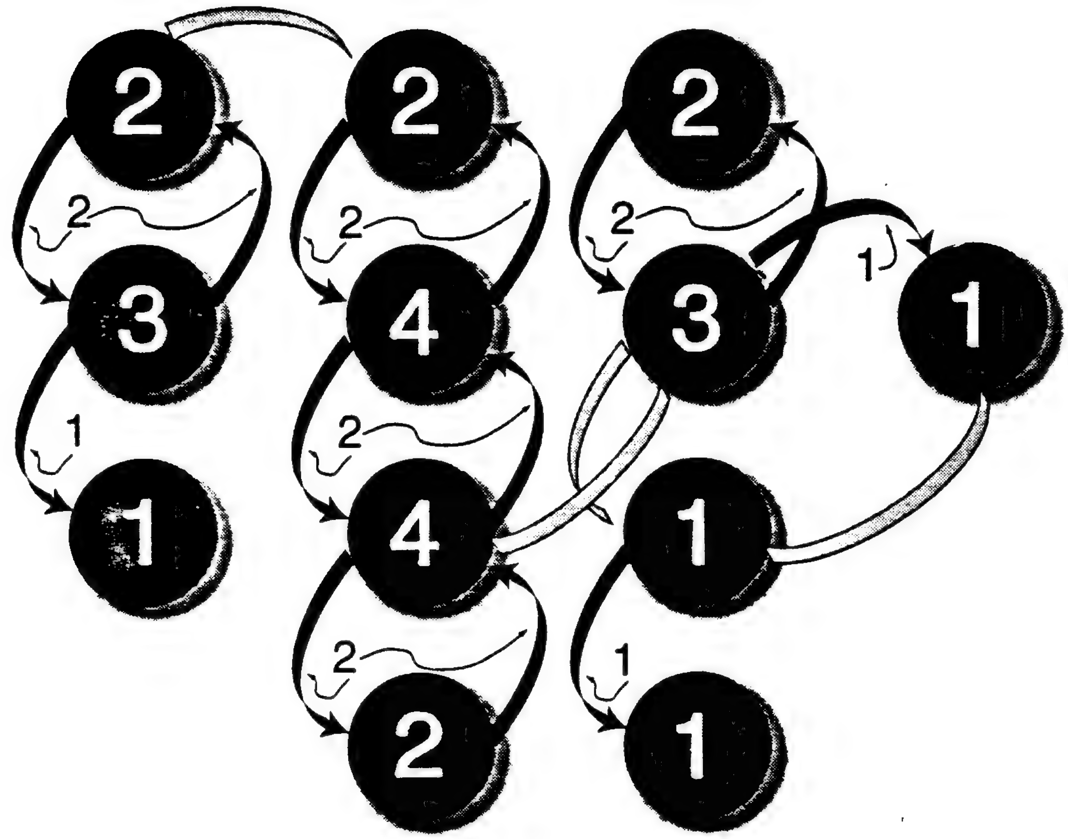

Figure 3-5:Counting Topological Features of the Example

tion of this metric defines a loop by the number of communicative acts (represented by arrows) there are before the utterance is resolved. But we have found that an accurate approximation simply counts the apparent loops. For instance, in Figure 4, acts 6 and 9 appear visually as a two part loop, though strictly speaking they are part of a more complex communication. So, defined this simple way, the example has three one-loops (one-way arrows) and five apparent two-loops. These are added in a weighted fashion similar to the distance metric, so what we call the *Time Delay* metric for the example would be $3^1+5^2=26$. This is calculated in a way similar to the node-oriented equation except this time its arrow structures, or loops that are counted. Figure 5 shows that there are 3 arrows which are dead-end acts, noted with the number one to show that they are loop structures constructed of one arrow. These three raised to the first power are our equation's first term. There are five loop structures composed of two arrows, producing our second term, five raised to the second power.

The resulting two numbers (44 and 26) are simply added together to give a raw metric of the process's agility; the higher the number, the lesser the agility. This composite metric would be used in comparing the agility of processes which differentiate two potential partners

There are associated metrics. Suppose that you wanted to evaluate the cost and time associated with making a *specific* change from one process to another, and you have a model of both. You would do a topology match between the two:

- The *Topology Match* measures the cost of changing from one process to another. The starting (or *before*) process is the baseline. Here we count nodes only, the percentage of nodes in the target process that have exact type matches in the baseline. Figure 3-6 shows an example, using our familiar process as the *before* and a process with a different topology as an *after*. Six of the twelve nodes of the process on the left have matches with the process on the right, so the metric is.50. A higher number indicates lower cost. (The relative cost of adapting from the right to the left would be.86, indicating that the adaptation would be easier.)

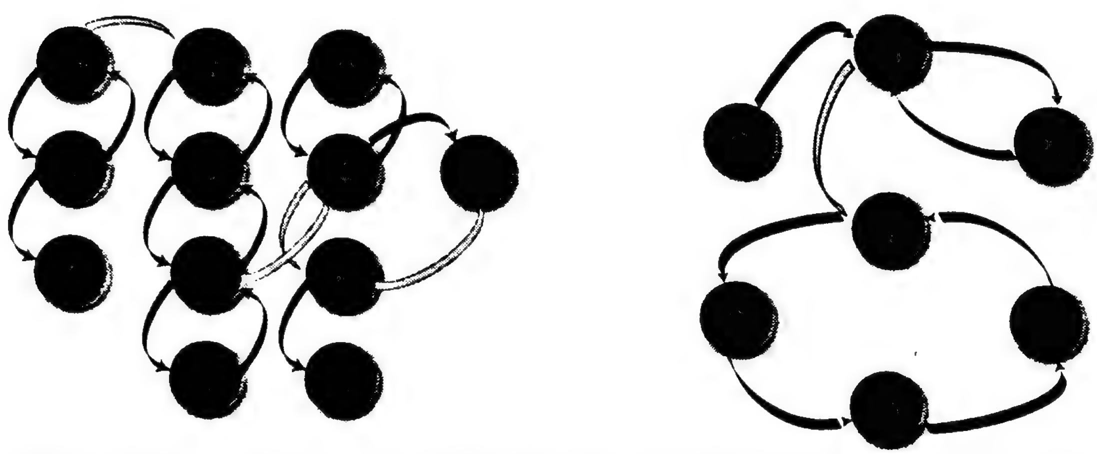

Figure 3-6:What is the Cost of Mapping from the Process on the Left to That on the Right?

Those metrics deal with individual processes. But a collection of agile processes does not necessarily add up to an agile enterprise; there's a second-order metric that we discuss below. But in many cases--essentially all cases where the extent of agility can be predicted and controlled--dealing with the first-order agility we've described is sufficient. Nonetheless, every process carries a different weight in the system. The following two metrics characterize that weight:

- *Importance* is the informal name for the comparison of the *distance* of the process to that of the enterprise, a comparison of the complexity of the nodes. Let's say that the entire enterprise has an (unweighted) number of 423, then 12 simply divided by 423 is the relative importance of the process within the enterprise's agility profile. That number, $^{12}/_{423}$ gets compared with similar weights of other processes to determine how they are added to evaluate the agility of the entire enterprise with the context being considered.
- A similar calculation takes place to determine what we call the *frequency* of the process, but this time, the process's unweighted number of loops is compared to

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that of the enterprise.

Distance	Total number of weighted nodes
Time Delay	Total number of weighted loops
Moveability	Topology match, internal
Importance	Nodes compared to the VEs total
Frequency	Loops compared to the VEs total

Table 3-2: Summary of the Intermediate Metrics

These two numbers summed provide the weighting function used when adding individual key processes across an enterprise to understand its relative agility. The latter two numbers do not require that all processes in the enterprise (or projected enterprise configurations) need to be modeled this way in order to get the enterprise-wide *distance* and *time-delay*. Because the *importance* and *frequency* are used relatively, the roughest of approximations will suffice.

We've validated the metrics both by formal reasoning and by retrospectively applying them to the dozen Agile Virtual Enterprise Best Agile Practice cases interviewed as a project of the Agility Forum in 1995.

The key metrics are the first two. These produce a raw number which can be used as a relative measure of agility of the process. Once the well-indexed case bases of agile practices being built by MIT, the Agility Forum, and perhaps others are ready, we will be able to:

- *Calibrate* the raw agility numbers to time and cost numbers in specific sectors. This will allow managers to register agility with other cost/benefit calculations in a balanced strategy.
- *Extrapolate* numbers into functions. This will allow managers to follow process design guidelines in engineering the ideal agility into processes, again following a balanced strategy.

3.4 AVE Model

[An earlier step of the method depends on breaking things down by a reference model. The model is described. Reference is made to the cost of populating the model and a case study to determine same.]

The metrics are intuitive and simple to calculate if you have modeled your processes in the nice tabular representation which leads to the Dooley Graph, but doing so may not be how you naturally see things in your organization. To prepare for populating such a table, we require:

- That there be a standard level of granularity for each complete process (each table). While many of the simpler uses of the metrics do not depend on such a standard granularity, the more interesting do (the trending and pattern matching of processes for instance).

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- That process dynamics be cleanly segregated. This means that we cannot mix worlds which operate according to different principles; truth, for example, follows different laws in legal, physical, and business process domains. The same is true of many principles. We avoid having to understand and manage the differences if we carefully separate them.

The Agile Virtual Enterprise (AVE) Focus Group, a multi-year open workgroup sponsored by the Agility Forum, tackled this problem. A standard AVE Reference Model was created which does this well. We won't describe the model in detail here, rather just give an overview.

The model is a two-dimensional table. The (horizontal) rows give a breakdown of the decisionpoints involved in conceiving, forming, operating and dissolving a Virtual Enterprise (VE). (The VE is seen as the more difficult case, subsuming the agility concerns of conventional enterprises.)

	Social/Cultural: Human Dynamics	Social/Cultural: Community Cultures	Social/Cultural: Business Cultures	Legal/Explicit: Business Processes	Legal/Explicit: Contracts/regulations	Legal/Explicit: Workflow	Physical: Logistics/Warehousing	Physical: Equipment	Physical: Laws of Physics
Opportunity ID									
Partner ID									
VE Formation									
VE Operation									
Reconfig/Dissolve									

Table 3-3: High Level View of the Reference Model

The (vertical) columns provide a substantial breakdown concerning the *infrastructures* of the VE, the major categories being Physical, Social/Cultural, and Explicit, the latter including Business Processes, Workflow, and Contracts/Regulations. Two more levels of breakdown are necessary.

The Row (Decision Point) Breakdown:

Part 1, Metrics Handbook

Opportunity Identification

- Opportunity Strategy
- Opportunity Exposure
- Targeted Marketing
- Search

Partner Identification

- Opportunity Strategy
- Partner Performance History
- Partner Search

Virtual Enterprise Formation

- Vision/Strategy Development
- Partner Criteria and Selection
- Enterprise Metrics
- Capitalization
- Product Liabilities
- Risk/Reward Strategy
- Operating Strategy
- Dissolution Plan

Virtual Enterprise Operation

- Performance Metrics
- Customer Relations
- Operating Practice

Virtual Enterprise Reconfiguration/Dissolution

- Identification of Need
- Residual Liabilities
- Dissolution Plan

The Column (Infrastructure) Breakdown of interest:

Social/Cultural Infrastructure

- Social and Psychological Laws
- Community Cultures
- Business Culture

Legal/Explicit Infrastructure

- Business Processes
    - Strategy Development
    - Supervise Risk/Reward Process
    - Supervise Engineering Quality
    - Work Scheduling
    - Depth of Customer Relations

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- Legal/Regulatory
  - Quality Assurance Agreements
  - Risk/Reward Contracts
  - How the Virtual Enterprise is Represented
  - Assignment of New Technology
  - Labor Agreements
- WorkFlow (Business Plan)
  - Planning Work Breakdown Assignments
  - Work Breakdown Responsibilities
  - Monitoring/Adjusting the Work Breakdown Structure
  - Arbitration/Adjudication
  - Routine Exception Handling

Physical Infrastructure

- Warehousing and Logistics
  - Virtual Enterprise Human Collaboration
  - Virtual Enterprise Product Collaboration
  - Customer's Pipeline, Product
  - Customer's Pipeline, People
  - Raw Commodities
- Equipment
  - How Modular
  - How Reconfigurable
  - How Scalable
  - How Relocatable
  - How Storable
- Physics
  - Geographically Limited Processes
  - Scale Limited Processes
  - Attention Limited Processes
  - Time Limited Processes
  - Accident Limited Processes

Definitions for this model have been freely and widely available in several formats, including at the Agility Forum's web site. We won't review the model in detail here; the important point is that it gives a structure for the analyses such as the metrics. Each cell in the model deals with a discrete decision (the rows) and involves a specific, discrete set of principles (the columns).

Each of the cells defines the scope, type, and dynamics of a specific process, or candidate process that a VE might be considering. That candidate is what we describe in the Communicative Act/Dooley Graph format described in the first part of the paper.

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The number of cells can seem daunting, but, fortunately, this is not bad news. By studying best practices, the group discovered that successful agility strategies focused on a very small number of cells: one or two major focus cells, a half dozen or so support cells and a few cells in which incompetence could create problems.

This was counterintuitive; we expected that agility would be a result of high scores in many cells, but that was not the case. Moreover, the cells which anchored a strategy varied widely, reflecting different leveragable strengths, business strategies, and market peculiarities. So there are few generic rules of thumb, no *dummy list* for painting by agility numbers. But for each strategy, only a few cells need to be modeled, as we've described above. This factor tends to make the system-wide evaluation of agility inexpensive.

As an example, consider the table below. Of the large number of possible cells to consider (1170), using the art of consulting skills we selected 20 that are likely to host an agility strategy for the defense prime, Consolidated Aircraft, which shares a profile with our case study prime.

	C.a.e Depth of Customer Relations	C.b.b Risk/Reward Contracts	C.c.c Work Breakdown Structure	D.a.a Human Collaboration
1.3 Targeted Market				
2.3 Partner Search				
3.6 Risk/Reward Strategies				
4.1 Performance Metrics				
5.1 Identify Need for Change				

Table 3-4: Specific Cells of Interest

The cell in the upper left is the cell for which the process described in the example's Dooley Graph. That cell concerns business processes which support how new markets are identified, and existing markets are served and extended through es-

tablishing strong and meaningful relationships with customers which are supported by each partner on the behalf of the VE.

While the AVE Reference Model is intuitive and simple, it is not the way most enterprises see themselves. Also, by identifying the process at this level to define the communicative acts, you fold in the agility strategy and implicitly the nature of the change. This is something that middle level managers, one important target user community, may have trouble envisioning.

Finally, interesting and useful agility involves partners, often suppliers. These suppliers are used to answering questions about how much things cost and how long it takes. They now sometimes answer questions about quality, but many may not be equipped to reveal process dynamics at the level we need. These three factors push the cost of using the metrics up.

How expensive it will be to see your processes in a small number of Dooley Graphs is an important issue. A case study was conducted with a defense aerospace supply chain, audited by an NSF Agile Manufacturing Research Center, to better understand these costs in a real scenario.

3.5 Use of the Metrics

[A few ways of employing the metrics are listed.]

There are a variety of ways that the metrics might be employed.

The easiest way is the one examined in the case study, that of building a supply chain with a specific type and extent of agility. In this case, you presumably know the general type of change and have a general strategy for response that leverages corporate strengths.

The case study deals with a common problem with complex systems: The development time of the product is much longer than the rate at which new, important technologies evolve. Best practices dictate that you build your supplier chain early and involve them intimately. But, as the product evolves, that supply chain needs to be agile, not artificially limiting the processes to commitments made early. Because the product in this case is a military weapon system, we also have the possible requirement for rapid refinement of its mission profile.

In this use, the metrics tell you which processes are more agile (based on your local definition of the need for agility). Where you are building an agile supplier base, it can tell you which supplier's processes give you the agility you need, both as individual processes and within the VE-level systems context.

As we've noted, if you have a case base which is applicable, the raw agility numbers can be converted to time and cost numbers for a related use. Suppose that you wanted to evaluate the time and cost of changing from one set of processes to another. For instance, from a prime's current processes, plus those of a tentative supplier set, you may want the time and cost of changing to another set in response to change. (This would include the savings of the agility gained within the capability of current processes).

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In this use, you supply a process, you get back a number measuring its intrinsic agility. As previously noted, we have a prototype/example tool that does the computation automatically.

In the system-level view, one would combine all of the key processes according to their weights to evaluate the agility of the enterprise (for that one change). A simple spreadsheet can do this, but we have a different system-level tool underway that supports this and the following as well.

Because you won't be certain what the exact change will be, you may want to do a statistical analysis of the likely changes to be encountered. These might be based on the tools used by the insurance industry to model risk. A spectrum of potential needs will result, with a spread of potential processes and process needs that might be brought into play. Sophisticated tools already exist to perform cost/benefit analyses using extrapolation and simulation, if the responses are well formed functions. Our metrics are these kinds of functions: continuous agility functions resulting from a family of related processes.

The way you'd look at a supplier or an enterprise in this view is not based on a single threat or opportunity, but a statistically distributed collection of possible events and options.

The movie industry does a similar type of analysis when putting together production VEs. When evaluating the potential profitability of certain firms, the investment community does similar work. The key in the investment community is knowing how likely a firm is to be profitable in the future, never mind now. In many sectors, this means the ability to survive and thrive in turbulence.

The most interesting use of the metrics is to go beyond evaluating processes, to suggest more agile processes, or to refine existing processes, then to simulate/validate the results. That is the direction planned for our future work, which will leverage other tools, including some under development by the sponsored agility community.

4 The Agile Virtual Enterprise Reference Model

[A few ways of employing the metrics are listed.]

4.1 The Process of Generating the Reference Model

[Hundreds of people helped create and validate the model. Some summary profiles of who and how are given.]

The Metrics Project was incubated within, and guided by a large group of concerned users and researchers. The way that the Project was conducted was novel: some elements of the project required focused effort by experts, who brought work to the group to be validated. But a major part of the work was actually conducted by the group, the creation and validation of a Reference Model and accompanying definitions for wide variety of Virtual Enterprises. This new model was needed because existing perspectives didn't provide adequate focus for the new goal of engineering and managing agility in a quantitative way. This section describes the Reference Model.

The Group consisted of two parts: a dedicated group, involving about 150 people which met about 25 times over three years for two days each meeting. These meetings rotated around the country, and were conducted under the auspices of the Agility Forum as the Agile Virtual Enterprise Focus Group, renamed in its final year the AVE Enterprise Development Group. Logistics, advertising and support were handled by the Forum. As well, the Forum took detailed notes, which were both mailed to a large list and published on the Web in order to keep all parties current.

The group was facilitated by Jim Jordan of the Consortium for Advanced Manufacturing, International; in the final year he was joined by Jerry Rosser of Hughes Missile Systems. Members of the group were from the following organizations:

- Small Manufacturers
  - Agile Web
  - Associated Fiberglass
  - Ceco Corp.
  - Contemporary Design
  - Hehr Power Systems
  - HighTech Marketing
  - Kavco Industries
  - Lider and Associates
  - Process Consulting
  - Rheaco Inc.
  - Tex Direct
  - Sherpa Corp.
  - Symbiotic Resources
  - Web Pipeline, Inc.
- Large Firms
  - AT&T

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- Boeing Commercial Airplane Group
- Boeing Military and Space
- Boeing Rocketdyne
- Deere & Co.
- Dupont Advanced Material Systems
- Eastman Kodak
- Ford Motor Company
- Goodyear Tire and Rubber
- Hughes Missile Systems Co.
- H. R. Textron
- IBM
- Lockheed Martin
- Lockheed Martin Vought Systems
- Lockheed Missiles and Space Co.
- Mack Truck
- Martin Marietta
- Metropolitan Edison Company
- Newport News Shipbuilding
- Northrop Grumman
- Raytheon
- Sikorsky
- Steelcase
- Texas Instruments
- U. S. Steel
- Westinghouse Electric

- Consultants, Services, Infrastructure
  - :2 Technologies, Inc.
  - Agility Forum
  - Andersen Consulting
  - Arthur D. Little, Inc.
  - Ben Franklin Institute
  - Center for Manufacturing Competitiveness
  - CommerceNet
  - Competitive Technologies Inc.
  - Conduit, Electronic Delivery Systems
  - D'Ancona & Pflaum
  - EDS
  - Enterprise Agility International
  - Executive Action Group
  - FKW Incorporated
  - Gemini Industries
  - Gaudiouse and Associates
  - Global Strategic Solutions

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- Gunneson Group International, Inc.
- Hall & Associates
- IBM
- Intelligent Systems Technology Inc.
- Institute of State and Regional Affairs (PA)
- Jim Bronson
- Knowledge Based Systems Inc.
- Lockheed Martin Palo Alto Research Center
- Manufacturing Application Center
- Mantech International
- Menlo Park Ass.
- Pennsylvania MILRITE Council
- Schnader, Harrison, Segal & Lewis
- Society for Manufacturing Engineers
- Strategic Business Management
- Symbiotic Resources
- Telart Technologies
- The Schraff Group
- VFD Consulting
- Virtual Learning Center

- Researchers
  - Aerospace Agile Manufacturing Research Center
  - Arizona State University
  - Consortium for Advanced Manufacturing International
  - Cornell Theory Center
  - Georgia Institute of Technology
  - Illinois State University
  - Industrial Technology Institute
  - Institute of Advanced Manufacturing Sciences
  - National Center for Manufacturing Sciences
  - National Institute of Standards and Technology
  - Pennsylvania State - Harrisburg
  - Sandia National Labs
  - Sirius-Beta
  - University of Indiana
  - University of South Dakota
  - University of Texas - Arlington
  - University of Texas - Austin
  - Western Kentucky University
  - Work and Technology Institute

8 This group included representation from a critical mass of other sponsored agility projects:

- The AIMS Project: a demonstration of automated, intelligent infrastructure for the supply chain lead by Lockheed
- The Agility Handbook Project, led by Competitive Technologies, Incorporated
- The Lean Aircraft Initiative, led by MIT
- The Affordable MultiMissile Manufacturing Program, being performed by four teams: Hughes/Texas Instruments, Raytheon, Lockheed and Loral
- The AgileWeb experiment in a Virtual Enterprise
- The Next Generation Manufacturing Systems Program, managed by CAM-I for the international Intelligent Manufacturing System initiative
- The similarly named Next Generation Manufacturing study being conducted by many groups, managed by the Forum
- Two of the three NSF Agile Manufacturing Research Centers (and many of their projects which we won't list here)

Complementing this group was a much larger *virtual* AVE group. The legacy of the metrics project involved some predecessor studies which involved a substantial number of researchers. Most of these offered to contribute. We placed a large number of issue papers on a central site which was provided by the Forum, and solicited input through an email discussion list. The list was also seeded with certain problem issues. A robust traffic, perhaps 600 messages, has been maintained both within the list and via private messages discussing list issues.

Subscribers to the list were from the following host machine addresses, which give some indication as to their nature. For instance, we can see that most are researchers, and a heavy international participation was maintained. What is not apparent is the nature of subscribers to commercial internet services. The breakdown among the three or four dozen people represented in this category is in the same proportions. One of the America On Line (AOL) participants translated and widely rebroadcast traffic within Japan.

- Non-United States
  - mlb.dmt.csiro.au (Australia)
  - info.fundp.ac.be (Belgium)
  - eunet.be (Belgium)
  - ax.ibase.org.br (Brazil)
  - ift.ulaval.ca (Canada)
  - ie.utoronto.ca (Canada)
  - lia.di.epfl.ch (China)
  - sap-ag.de (Germany)
  - iff.fhg.de (Germany)
  - ira.uka.de (Germany)
  - itmi.cgs.fr (France)
  - tm.tue.nl (Holland)
  - swi.psy.uva.nl (Holland)
  - idt.unit.no (Norway)

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- comu4.auckland.ac.nz (New Zealand)
- irl.cri.nz (New Zealand
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There were many special workshops and consultations at specific sites with groups, companies and other projects, which we will describe elsewhere, each in their proper place. What we wanted to do here was give some credit for the substantial work and wisdom which created and validated the Reference Model which we describe below. It constitutes effort which, in this element alone, leveraged the government investment many times.

All of this document, in various drafts of parts, was circulated by various means. Email, which is limited to text only, forced us to rely heavily on precise use of words rather than graphics, which often are more ambiguous.

4.2 The Reference Model

[The structure of the model is reviewed in detail.]

With the help we note above, the various generic processes of the VE have been broken down in a way that is both generally useful for agility considerations, and also specifically supports the first step of our process.

The conventional views of the enterprise as a collection of *functions* (personnel, manufacturing, etc.) or *resources* (people, machines, intellectual property) are not particularly useful in considering agility. Instead, what is of interest are decompositions based on value-added processes and capabilities to provide that value-added.

Toward that end, the life-cycle of the VE has been broken down into the following major *processes*. Each process involves *decisions*; these decisions use *tools* and *methods* which are informed by our *metrics*. Each of the categories and subcategories noted below capture the process involved when a decision is made. A decision in this context is one which involves cost and commitment.

The model is usually represented as a matrix at its high level categories. The rows are key decisions, the columns are infrastructures.

First we describe the processes. These are organized by the life cycle of the VE, from birth to death. The major breakdown is roughly chronological, but the divisions below that are not.

Then we define the infrastructures. Differences among infrastructures require some special attention by the reader; a more rigorous breakdown and definitions are used here, and some terms may differ from their more informal meanings. The goal here is to tease different underlying mechanics into different categories; for

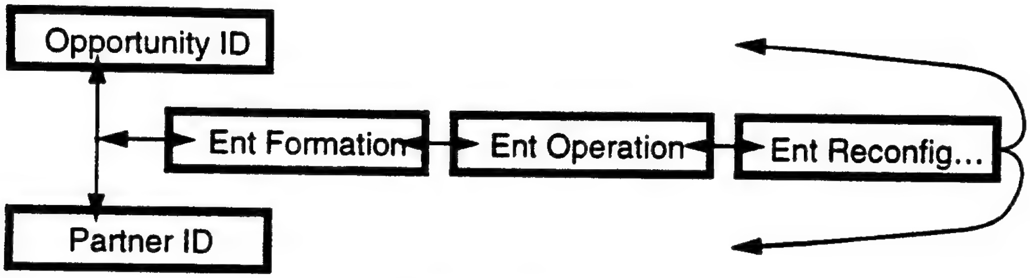

Figure 4-1:Major Life Cycle Categories

instance, the things that bind a VE culturally are quite different in nature than those that tie things legally or by business processes. The importance of making these distinctions pays off later.

In both axes of the model, we worked hard to fit all manner of business models and market sectors. The model at the high levels has been validated in a wide range of for-profit enterprises. The lowest level of detail in the infrastructure is domain dependent; details of aircraft enterprise infrastructures differ from those of movie or food sectors for instance.

Finally, we give some examples of specific process decisions, specific cells in the matrix, which might be made by an enterprise.

All of this depends on a large collection of definitions, qualifiers and special considerations. Rather than encumber the reader at this point, we've collected these in Part 2. Among other things, you will find there the definitions of agility, Virtual Enterprise, metrics and such on which we depend.

The life cycle processes are listed here as five main categories, each with subcategories.

4.2.1 Process Category 1: Opportunity Identification

[Components in the model dealing with how a prospective Agile Virtual Enterprise identifies whether an opportunity exists and what its nature is.]

The main category assumes that some agent, either a potential lead for an AVE or some tentative collection of contributed experts, has the charter to identify, refine and/or characterize the opportunity. This could be a broker who has no capability cogent to the AVE's operation. But the simplest case is probably the most prevalent today: identification and refinement of an opportunity by one firm which has a key relevant core competency. Then that firm seeks to fully understand the characteristics of the opportunity to define the requirements of the AVE which must be formed in response.

Processes in this first category may proceed simultaneously with the those of the second Partner Identification, with a better understanding of the capabilities of a future AVE informing an understanding of the market/opportunity. As an option, simulation, Virtual Manufacturing, can be used to support both of these two categories.

4.2.1.1 Opportunity Strategy

In order to identify an opportunity, the identifying agent needs to have a strategy. The strategy must be explicit and well reasoned, because results from the strategy need to be understood and adopted by potential members of the AVE. There should be no question of principles in the strategy; otherwise, each potential member would have to independently conduct their own analysis. The formation of the AVE would be unnecessarily encumbered.

Within the strategy, there should be a means for protecting the disclosure of details of the opportunity to potential partners, because full disclosure could mean empowering a competitor. The assumption is that market information will be distributed among firms, at least in the Type 1 AVE, so that a combined overview must be synthesized from several sources.

Relating to the above, early in the entire process there must be a consistent understanding of who is the *lead* for the AVE (at least for this phase). There may be brokers and consultants involved who are specialists in the strategy. The strategy should be based on a consistent method for defining and determining core competencies. There will probably be a simple relationship between characteristics of the opportunity (as defined by the strategy) and core competencies of the partners.

The strategy also needs to incorporate a vision of what constitutes success. This definition of success will form the basis for many of the processes which follow. Finally, the strategy must have a way of determining whether the opportunity is a strong candidate for being addressed by a feasible AVE. At this point, the AVE criteria are probably unknown.

Example attributes of this process that would make it agile would be:

- Responds quickly (appropriately fast)
- Forward, *panoramic*, view of market opportunity
- Explicit, well reasoned, and consistent process for opportunity ID/assessment
- Continually assess opportunity & competition
- Accommodates continual and unexpected change
- Repeatable method for applying competency definitions to partners

4.2.1.2 Exposure

Independent of the strategy (which is analysis oriented), there needs to be a collection of actions. This and the remaining subcategories represent various types of actions supporting opportunity identification.

The lead should have an exposure mechanism and use it to inform the customer(s) that there is an intent to address the opportunity. Ideally, the customer would have a role in the AVE. Simultaneously, actions must be taken to expose intent and information with potential partners. How this *advertisement* occurs may be different in the future. For now, it is likely to be critical in successfully forming the AVE

and addressing the opportunity. It may be that an entity will advertise its intent to address a class of opportunity rather than a specific opportunity.

Agility will result if the exposure can be to many *customers*, for many trial situations, at low cost. It is also essential that fast action can be taken when the situation looks promising. Such speed infers that a pre-AVE situation can be evaluated by sufficiently high confidence metrics to commit resources.

Example attributes of this process that would make it agile would be:

- Multiple mechanisms to inform/expose customers (internal and external) that there is an opportunity and an intent to address the opportunity
- Individual core competencies advertised

4.2.1.3 Targeted Marketing

There is a collection of actions which may actually intervene in the marketplace to help incubate or firm up an opportunity. This process is where the customer becomes integrated into the AVE at an early stage to incubate conditions. The process will be more sophisticated than opening a communication channel, since many customers may not know what could be possible, or not have recognized changing conditions.

This process includes the actions employed that clarify the needs and match them to core competencies in the AVE, effectively defining the need for AVE partners. The result is a *solution* in response to the need. The *lead* may go through a process of educating the customer(s) to help create the demand for an opportunity. Perhaps the definition can be directed to maximize the competitive advantages addressed by the potential core competencies of the AVE.

An AVE will almost certainly include the customer in the partnership in some way beyond a buyer-seller relationship. Ideally, some core competencies in the customer base will be leveraged to advantage.

Example attributes of this process that would make it agile would be:

- Insight to changing key buying factors
- Initiator may educate the customer to help create the market demand for an opportunity
- Leverage competencies

4.2.1.4 Search

Sometimes the opportunity is not apparent, as is implied in the two subcategories noted above. Regardless, each firm (or stable partnership) should be constantly searching for new ways to leverage its competencies. Therefore, there will be a set of processes which scours new, perhaps unconventional markets empowered by new partnerships. This collection of processes will vary depending on the sector and the creativity of the organizations.

Apparently, the search in the AVE context will assume capabilities from new partnerships. These will come either from strawman partners or generic capabilities. There needs to be science employed (based on the strategy) in order to evaluate tentative opportunities. Because the costs of AVE are different from non-AVEs, this science (however implemented) may be a key competitive tool.

As with Opportunity ID: Exposure, an AVE will be simultaneously investigating many possibilities, including very unfamiliar ones. It will leverage many short term relationships with various potential partners at reasonable cost.

Example attributes of this process that would make it agile would be:

- Simultaneous investigation of many possibilities
- Scours new, even unconventional markets utilizing novel analytical techniques
- Electronic opportunity search for possible solutions to current needs or problems that could lead to new products
- Use stakeholders to identify possible leads

4.2.2 Process Category 2: Partner Selection

[Components in the model which address how the need for partners is identified and specific candidates are evaluated.]

The category generally addresses the selection of partners. Type 2 & 4 AVEs assume that the partnerships pre-exist, so they will largely omit this category. The others may choose to perform these actions in parallel with the opportunity identification and crystallization because it could reduce the costs associated with the strategy and improve the relationship with the potential customer. But nominally the business decisions will be first associated with identifying an opportunity, then a partnership team.

Type 1 partners are envisioned more as partners, compared with Type 3 relationships, which may resemble traditional supplier relationships. It is currently debatable how distinct these two types of relationships are in the AVE context.

As with Category 1, an AVE will be *promiscuous*, forming and dissolving many partnerships among a large portfolio at low cost. The partnerships will have loose coupling, being limited only to the need to address the opportunity well. This might be accomplished by having each partner tend to be self-organizing in the context of the Virtual Enterprise. And it may be aided by some partners' migration of organization-building tools from prior AVEs.

4.2.2.1 Partner Qualification

As noted in Opportunity ID: Opportunity Strategy, there will be a strategy which can be commonly shared, and which has a standard method for defining core competencies. Also, the core competencies required by the opportunity will have been identified. This process concerns revealing, with a high level of confidence, the core competencies of candidates, together with other key business indicators.

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A method is required for applying the competency definitions to partners. Problems could arise due to dishonestly and variations in the definitions. While core competency evaluation must be determined, there are other factors to qualify: such issues as quality, technical, capacity, and financial criteria. These criteria will be evaluated somewhat differently in an AVE context than in a traditional context. There needs to be a quick, cheap method of getting this information with sufficient fidelity.

There may be methods for prequalifying partners, one of them being the reliance of a third party to precertify them. A question of liability arises from mistakes or misrepresentations made during this process. There must be a process to address this issue of accountability.

Overall, there will be available a class of *metrics* which address the ability of a firm to enter into an AVE, independent of the value its competencies bring to the AVE. (The ability to form quickly, flexibly.)

There will be an independent class of metrics associated with the level of agility the firm will bring to the AVE during its life, *the ability to support agility in the AVE*, external to the firm.

There may also be a third class of relatively independent metric which measures the agility within the internal operations of the firm, the *agility in own processes*.

If there are no qualified partners, or if an unqualified partner must be included for some reason, then there must be a provision to make that partner qualified.

Example attributes of this process that would make it agile would be:

- Evaluate factors such as quality, technical, capacity, financial criteria, etc.; must be done quickly and cheaply yet maintain sufficient fidelity
- Provision to make a potential unqualified partner qualified
- Minimum requirements (information system, communications, resources, etc.) identified as: existing; needed; not needed

4.2.2.2 Partner Performance History

A key issue in forming AVEs is the matter of trust. This collection of processes facilitates trust. A method is required to reveal a partner's history based on proven quality, delivery, and other criteria. A related method is required to determine which of the traditional and new measures of a firm's history is cogent to the AVE. There could be a single AVE profile, or this could be situational.

This subcategory is differentiated from the previous one by focusing in on specific, historic information. The previous category spans many strategies for qualification. This one is concerned with data from the past. Special analytical tools will be required to map past situations to the current one since it is presumed that the situations will widely differ.

One agile strategy will be the sharing, possibly selling, of information among current and past AVEs. Historic information may be a sustained asset of dissolved

AVEs, or there may be a new infrastructure. Generally, the issues are the same as with the prior subcategory.

Example attributes of this process that would make it agile would be:

- Has trust been demonstrated? i.e. proven quality, delivery, ability to deal with/ operate, to share share/sell information without violation of trust, etc.
- Ability to apply/map past performance to new situations (look at historical data - safety, strikes, performance responsiveness)
- History of face to face *handshake* (informal) agreements being trustworthy.
- Is the potential partner able to form and dissolve many partnerships at low cost - relative to input?

4.2.2.3 Partner Search

The two processes noted above presume that some candidates have been evaluated. But it is likely that a more exhaustive search for candidates will be desirable.

It is advantageous to have multiple methods for searching for candidates. It is an open issue what are the best search criteria or search forums. It is debatable whether a firms' self-presentation will reflect the appropriate criteria. In other words, it is unknown whether widespread AVE formation depends on a not-yet-developed search infrastructure.

An agile *lead* will have strategies to search out many potential partners. Potential AVE partners will be agile by making themselves easy to be found and evaluated.

Example attributes of this process that would make it agile would be:

- Initiator should look both internal and external to the walls of company - *outside the box thinking*
- Multiple methods/technologies (intelligent agents, brokers, etc.) for searching

4.2.3 Process Category 3: Formation (Business Case Development and Commitment)

[Here we describe how this part of the model supports various decisions concerned with the formation of the virtual enterprise.]

Having identified the opportunity and partners, the AVE must fully build the detailed business case, make the multiple commitments required, and form the AVE. There are a substantial number of issues concerned with this process. To a large extent, everything until this point has been performed with the purpose of building the business case and making the commitment. It is at this point that major resources are committed.

But it is also true that the AVE (in all its infrastructure) must be carefully established in ways to insure success in the future phases (operation and dissolution).

The key to agility in the Virtual Enterprise is in this category. An AVE will, in addressing the formation process, exhibit several agile attributes. The most notable are: Reusability (in infrastructure components from prior AVEs); *Scalability* (in escalating core competencies of partners to the AVE as a whole); *Self Organizing* (in distributing the *binding* infrastructure among the partners); and *Loose Coupling* (by lowering the cost of removing partners as conditions change).

4.2.3.1 Vision/Strategy Development

The AVE has to be founded on an explicit statement of purpose. This can be built on the foundation of the strategy noted above in Opportunity ID: Opportunity Strategy. The strategy is likely to be *mission-based* and differ from the host organization's strategy in being based on partially temporary infrastructure. The strategy must incorporate a sense of the life-span of the AVE, how it is going to change in response to expected conditions, and how it is going to institute agile practices for unanticipated change.

A particular AVE will have to accommodate new types of agile practices, not needed in each host organization.

The vision will have been presented as an early template for determining the feasibility of the specific AVE. While more detailed decisions related to formation are noted below, they should all relate to this vision. Unanticipated events/conditions may change some of those implementation details, so this vision is needed as the constant core. Included in the vision are some basic principles about the overall goals and roles.

Agility will be seen in how readily and robustly the vision can be developed and shared among the partners.

Example attributes of this process that would make it agile would be:

- Explicit statement of purpose; built on the opportunity strategy; mission-based modified strategic plan;
- Incorporate a sense of the life-span of the AVE
- Agreement on how to handle both anticipated and unanticipated change including continual competition assessment
- Continual customer assessment (new & old)
- The customer will have a role in the AVE ownership
- A common set of ethical standards (Code of Ethics) not legally binding, which is an expression of values which facilitate an environment of trust and cooperation

4.2.3.2 Partner Criteria and Selection

The subcategory's process is the actual selection of and commitment to partners. In an ideal case, it should fall out of the processes that precede it. However, it is possible that things will not have proceeded in an orderly, slow fashion to this

point. So there need to be a collection of catch-up processes of filling in the gaps and clarifying all the roles.

This process is based on the go/no go decision and involves implementation details about the relevant infrastructures.

Agility will be seen in how quickly resources can be committed to close the partnerships with specific candidates. The commitment will be dependent on the agility exhibited in Category 2: Partner Selection.

Example attributes of this process that would make it agile would be:

- Core competency tradeoffs among AVE members for time and cost
- Go/no go decision shared quickly throughout the initiating organization and partners

4.2.3.3 Enterprise Metrics

Part of the formation process is in determining the metrics to be applied across the AVE. These will be based on traditional financial and operational metrics. They should be capable of identifying change downstream. That is, they should be capable of determining not only whether goals are being met, but also to anticipate problems/changes. Certainly, there are overlaps between these metrics and the agility metrics noted in Partner ID: Partner Qualification. One can be conceived as a subset of the other.

Note that the metrics of this subcategory are not the more general set of metrics addressed by our metrics project. Instead, these metrics deal only with the relationships and interactions which need to be addressed in forming the AVE by integrating processes from diverse sources.

Agility will be exhibited not in the acceptance of these metrics, but in their facile use.

Example attributes of this process that would make it agile would be:

- Consistent roll-up of heterogeneous metrics across the AVE
- Capable of identifying change downstream
- Anticipatory in nature

4.2.3.4 Capitalization

This process deals with the detailed determination of who commits what capital (and other assets) and with the commitment of those assets. It means that new financial/legal infrastructure must be created. Where intellectual property is involved, this needs to be evaluated as a contribution. It will be necessary to set the method by which the value of intellectual property (and other dynamic assets) is determined as the AVE is operated and the value changes.

As with most of the allied subcategories, agility will be seen in how quickly, competently, and cheaply the processes are conducted.

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Example attributes of this process that would make it agile would be:

- Better, faster, cheaper financial/legal infrastructure
- Dynamic assets - recognition that value may change

4.2.3.5 Product Liabilities

This process deals with assignment of all anticipated liabilities, including those which are improbable. This process also creates new legal infrastructure, which is related to that noted above. Included in the process is the scoping of *warranties*: who is responsible for what and how the warranty profile is presented to the customer. Note that there is a separate class of liabilities associated with the process (ecological or social suits for example) which are not bound to the product. These are addressed elsewhere.

Agility will be exhibited in the legal infrastructure. Speed and cost are not issues here; instead, the problems concern accurate anticipation.

Example attributes of this process that would make it agile would be:

- Assigned responsibility for anticipated liabilities
- Accurate anticipation for all potential liabilities is the key - not speed and cost

4.2.3.6 Risk/Reward Strategies

The previous two processes are related to contracted *commitment*. This process focuses on determining *rewards* in detail. Presumably, risks and rewards will be co-defined, with reward based on risk; risk is one of the metrics which must be captured in the subcategory on metrics which follows contribution, see Formation: Enterprise Metrics. Those metrics should be capable of identifying failure modes as a way of assessing negative reward.

The process should accommodate the reality that the risk contribution may not be naturally reflected in a dollar amount. Examples are: name, image, goodwill, and market intelligence. Included in the risk metric should be a threshold at which the dissolve/reconfigure processes of Category 5: Reconfiguration and Dissolution are triggered.

In addition to the *speed, correctness and cost* issues normal to Category 3: Formation, agility in an AVE will be improved if the risk/reward structure is itself agile, capable of responding to change.

Example attributes of this process that would make it agile would be:

- Establish an atmosphere that *all* are viable value-add members of the business
- Inter and intra dependency/results

4.2.3.7 Operating Structure

The processes of this subcategory address the creation of the *operational* infrastructure to be used in the AVE. Infrastructures need to be created to support the

relationships which partners have with one another. Reporting and supervisory relationships need to be established. The *hierarchy* of partners needs to be explicit. How top management spots are filled and possibly with whom need to be determined. It may be that a role unique to AVEs needs to be established: that of scorekeeper/adjudicator. This role may be supplemented by processes which anticipate and neutralize conflict, possibly through team-building activities.

An AVE will be agile in its formation if both the aggregate and components of the partnership can bring the operating structure up quickly and cheaply. The resulting AVE will be agile in operation if the partnership has been designed with agility in mind. As a result, this subcategory provides the bridge between agile formation and agile operation.

Example attributes of this process that would make it agile would be:

- Permits intra-AVE member learning, leadership, team building, brain storming, empowerment, etc.
- Minimum corporate leadership, maximum AVE teams cooperation; P&L responsibilities at the team level within member companies
- Potential scorekeeper/adjudicator established

4.2.3.8 Dissolution Plan

AVEs (certainly Types 1 and 3) are presumed to be temporary, based on a specific opportunity. Therefore a dissolution plan must be devised, and the infrastructure for dissolution build into the AVE when it is created. As one necessary component, a trigger or threshold needs to be set to establish when the opportunity of the occasion for the AVE ceases to be productively addressed.

As mentioned in the introduction, a Virtual Enterprise must have this plan in order to be agile. The best practice expected will be in an AVE which has clearly thought out the plan and contingencies above and beyond a simple intent to dissolve.

Example attributes of this process that would make it agile would be:

- Built into the creation of the AVE
- Trigger/threshold established for Dissolution/Reconfiguration: Identification of Need

4.2.4 Process Category 4: Operation

[The model supports processes involved in operating the virtual enterprise.]

Having established the AVE, it must be operated. It should look like a single organization from the outside. That is, the operation should have an external view which looks like a conventional organization. But there are likely to be operational factors unique to the AVE. These may be similar or identical to operation of a large, decentralized manufacturing operation (as in automobile or large aircraft enterprises).

4.2.4.1 Performance Measures

This collection of processes will implement metrics which measure individual components at the micro level, the lowest level at which the strategy of the AVE is concerned. But these should combine at macro levels: one of which are the enterprise metrics of Operation: Capitalization. Therefore, these metrics support the predetermined risk/reward structure. Some AVEs may integrate processes to the extent that boundaries between firms are blurred. In this case, the AVE's performance measures take on the additional responsibilities of managing work normally the purview of a member firm.

Agility in operation can occur only if managers can understand what is happening both within the AVE and within its context. A best practice would have in place sufficiently clear metrics to enable the manager both to understand and to control dynamic conditions.

Example attributes of this process that would make it agile would be:

- Responsive to dynamic conditions which require real-time or near real-time performance measures
- *Federated* metrics
- Delineation of AVE member boundaries required to identify bottlenecks, delays, etc. in order to maintain accountability

4.2.4.2 Customer Relations

The AVE must appear as a unified organization to the customer, so processes must be established to support this transparency. Presumably, some of the risk/reward structure will be based on customer satisfaction. This necessitates a metric which measures satisfaction and assigns traceability to the proper component. Processes have to recognize and ideally to measure *intangibles* such as goodwill. Also desirable are processes which support giving back to the community, society, and environment.

Conventional agility is supported in an AVE which has agility in this respect. By being in touch with the customer, presumably by their membership in the AVE, market changes can be better anticipated and understood.

Example attributes of this process that would make it agile would be:

- Processes to support transparency of the AVE; looks like one entity to customer
- Metric to measure customer satisfaction in order to assign within the risk/reward structure

4.2.4.3 Operating Practice

Once the AVE is up and running, in important ways it should function as if it were a single organization. Boundaries between firms will be minimized, so the processes used in some types of AVEs will be managing certain processes within the AVE's components instead of merely administering boundaries between firms.

This subcategory is intended to incorporate all the Best Agile Practices from other studies relating to agility in a single corporation. However, there may be additional practices unique to the AVE.

All of the Best Agile Practices associated with the agile operation of an enterprise are incorporated here by reference.

Example attributes of this process that would make it agile would be:

- Integrated processes across the AVE's components to maximize process synchronization
- Ingrain with continuing the virtual thinking at all levels of the AVE
- Scalable, reconfigurable, reusable

4.2.5 Process Category 5: Reconfiguration and Dissolution

[The model supports processes associated with the end of the virtual enterprise and its possible recycling.]

At a predetermined point, the time will come when the opportunity has been fully satisfied or otherwise changes. It will then be time to dissolve or radically reform the AVE. This point is presumed to be mutually understood within the AVE, and may be tracked by a metric.

Moreover, that point probably is well outside the normally encountered dynamism addressed by agility practices of the previous category. However, reconfiguration may be a *normal* agile response in some types, for example Type 3, Agile Supplier Chains. If the AVE is to be reformulated, this process will feed back to the first category.

It appears clear that agility here cannot be created; it has to be inherited from earlier processes as described above, particularly in Operation: Dissolution Plan.

4.2.5.1 Identification of Need

The AVE will have predefined *sunset conditions* related to the situation of the initiating opportunity. A process is needed for monitoring those sunset conditions, with special metrics in some cases, to identify when the formation of the AVE needs to be revisited. This process will trigger (and provide information for) fundamental change of both the nature and the structure of the AVE.

Once again, agility is tied to *metrics*. The metrics central to this process derive from the environment, see Opportunity ID: Opportunity, Strategy and Operation: Customer Relations and the predetermined plan (see Formation: Vision/Strategy Development, Formation: Partner Criteria and Selection, and Operation: Performance Measures.

Example attributes of this process that would make it agile would be:

- Revalidate assumptions of pre-defined, mutually understood criteria for dissolution or radical reformation
- Human decision maker is supported by intelligent decision aides coupled to *trigger matrixes*

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4.2.5.2 Residual Liabilities

Whether dissolved or reconstituted, there needs to be a set of processes to identify and assign responsibility for residual liabilities. Examples would include warranties, environmental concerns, employee benefits, and product liabilities. Note that even *normal* operations or changes in the AVE may require liability reassignments. It is possible that the assignee might not have been a partner in the AVE. It may instead be a partner acting in a new role, or it may be one or more successor AVEs.

As with all issues in this category, the agility will have already been built in by this time, in the legal and social infrastructure.

Example attributes of this process that would make it agile would be:

- Validate assumptions and execute pre-determined processes to identify and assign responsibility for residual liabilities based on current opportunity. This process may require a total *rethink* of the original plan.
- Assignee may not have been partner in the AVE (may be partner acting in new role, may be one or more successor AVE's)

4.2.5.3 Asset/Equity Dispersal

A series of processes are required to distribute assets and equities. This is similar to the liability assignment. But whereas liabilities are not precisely quantifiable, assets and equity should be more so. So the processes are likely to be more metrics-based, cost-based. However, assets could also include *intangibles* such as goodwill. This subcategory does not include profits dispersal, since that should have been handled in normal operation.

Moreover, assets form the basis for reconfiguring or otherwise reconstituting the AVE.

This subcategory, as with the preceding one, will be addressed by previously determined agile mechanisms. However, both need themselves to be agile to respond to unexpected conditions in the dissolution, for example catastrophic failure.

Example attributes of this process that would make it agile would be:

- Validate and execute pre-determined process of dispersal
- Dispute resolution, if necessary, (mediation, arbitration, court system, etc.)
- Metrics or cost based

4.2.6 Infrastructure Elements

[Another dimension of the model are the infrastructures. They are all described here.]

Infrastructure forms the second axis or dimension of the model. The idea in this breakdown is to separate the different dynamics that bind the AVE together. In agility considerations, we focus on the *coupling* of different entities in the enter-

prise. The laws and behavior of workflow differ fundamentally from those of, say work safety regulations, so we strive to make the differences clear in the model.

Unfortunately, some of the terms we use for these *infrastructures* are also used in work by others to mean different things. There doesn't seem to be any way around this, since all the useful words have been overloaded. So careful definitions must suffice.

4.2.6.1 Information Infrastructure

Information Infrastructure is a fundamental infrastructure dealing with the nature of communication. This is not to be confused with the arrangements for automated support for the other infrastructures. Automated support is implicitly in the other categories; for instance computerized workflow support such as modeling and operating control systems are considered components in the Legal/Explicit Infrastructure: Workflow area.

This infrastructure deals with the underlying means for communication and coordination, and includes verbal, written and graphical notations and the logics and abstractions which underlay them. The project has some results in notations, and information-theoretic (meaning situation-theoretic) approaches to describe and partially understand the mechanics here. Since these are not engineerable at the VE level for the individual enterprise, we ordinarily do not include this infrastructure.

The addition of metrics to the disciplines of enterprise engineering and operation is at this level.

4.2.6.2 Social/Cultural Infrastructure

The infrastructures below deal with dynamics in the enterprise which is implicit while the two below are defined explicitly; elsewhere we call this the *soft* infrastructure where the others are *hard*.

- *Social and Psychological Laws*

  This subinfrastructure concerns behavior that seems to be *hard-wired*: certain personality types, interactions, and reproducible group dynamics. Some enterprise engineering can be accomplished here, but the understanding of the laws at work is relatively crude. Engineering often consists wholly of the evaluation and selection of individuals and teams that work.

  Example attributes of this infrastructure that would make it agile would be: AVE leadership is attentive to and leverages basic patterns of human behavior, group dynamics, and individual/team motivation.

- *Community Cultures*

  Community Culture subinfrastructure deals with influence and communication networks and associations which are driven by identification with factors such as nationality, ethnicity, race, and gender. Many other identities are involved: club, religious, class, political and trade affiliations are only examples.

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Example attributes of this infrastructure that would make it agile would be: methods for readily tailoring processes, contracts and workflow to leverage special cultural strengths and weaknesses (e.g. Korean vs. Mexican autoworker schedules); method to proactively identify potential work flow descriptions due to cultural differences.

- *Business Culture*

Business Culture is a special kind of community culture that may cut across (or federate) many communities. It is unique in being sustained, possibly consciously generated, by the enterprise.

Example attributes of this infrastructure that would make it agile would be: synergism of business processes leveraging the diversity of business culture (allows heterogeneous cultures in the AVE).

4.2.6.3 Legal/Explicit Infrastructure

The infrastructure is defined by processes that are explicit and possibly engineered in the enterprise. Explicit means that they are articulated somewhere. It includes processes that deal with how the business is run, who manages whom, and who makes what decisions. The rules that influence job descriptions are included. In the virtual enterprise, this concerns who does what in supporting interactions.

- Business Processes

The *sub-infrastructure*, Business Processes means that the processes deal with such things as the risk/reward system, the supervisory and monitoring relationships and *ownership* of various elements of the enterprise.

Example attributes of this infrastructure that would make it agile would be: distributed ownership of the strategic planning process, including spread into the customer base; distributed responsibility for customer relations and modeling expectations; flexibility in how the monitoring for rewards is handled; ability to recognize and leverage risk by a partner when the reward is AVE-wide; ability to reconfigure supervision of product/service quality/completion; ability to redistribute who does what and when in terms of actual value-added; support system for innovation is established and in place

A more specific breakdown can be made. At this level, we find that the details vary according to different business models and market sectors.

- *Strategy Development:* concerns the conventional business strategy that would for instance be in a business plan, concerning specific approaches to markets, competition, partners, etc. A key component of this infrastructure is who owns/can adapt the strategy.
- *Supervise Risk/Reward Process:* addresses the explicit plans for who gets paid how much for what. A key factor is who owns/can change the risk/reward process.
- *Supervise Engineering Quality:* deals with who owns/can change the processes which match customer demands for quality with the VE's

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processes, and what the processes are to provide that supervision.

- *Work Scheduling:* who decides and can change who does what within the VE.
- *Depth of Customer Relations:* address who is and what processes are responsible for understanding, dealing with, and satisfying the customer. Includes the processes to change the customer and how they are dealt with.

- Legal/Regulatory

The *sub-infrastructure*, of Legal/Regulatory concerns the processes that deal with *legal* instruments. Internally, these would be contract clauses; externally, they would be codes, laws, and regulations.

Example attributes of this infrastructure that would make it agile would be: the ability to *simultaneously* manage different models of culture; use of contract templates based on case law and other precedents; a proliferation of agents to fill legal needs of discovery, certification, and indemnification; flexibility in how contracts support fluid, and flexibly scoped (e.g. partner vs. AVE) risk/reward scenarios; flexibility in who is the customer (e.g. licensing by Disney moving from films to tapes, parks, toys, etc.); flexibility for how intellectual property is managed during and after the activity of the AVE; pre-determined, pre-prioritized dispute resolution processes.

A more specific breakdown:

- *Quality Assurance Agreements:* This specific set of contracts and regulations concerns responsibilities and processes involved with measuring, monitoring and guaranteeing the quality of each partner's effort in the context of the VE.
- *Risk/Reward Contracts:* This specific set of contracts and regulations concerns responsibilities and processes associated with how each member gets reimbursed (or receives other benefit) for benefiting the VE. Naturally, penalties for harming the VE are included.
- *How VE is Represented:* This specific set of contracts and regulations concerns responsibilities and processes that support how each member contributes to the relationship with the customer.
- *Assignment of New Technology:* This specific set of contracts and regulations concerns how new intellectual property gets developed, used in the VE and used outside the context of the VE.
- *Labor Agreements:* This specific set of contracts and regulations concerns how the VE deals with workforce issues that are normally covered in continuing institutions: pensions, insurance, continuing education for examples.

- WorkFlow (Business Plan)

This *sub-infrastructure* includes processes that are explicitly defined to determine the sequence of work. It differs from Business Processes; that group deals

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with processes in the enterprise that affect product (or service); this group deals with processes associated with the product that affect the enterprise. Physical Infrastructure: Warehousing/Logistics deals with physically determined procedures/rules; this group's rules are defined by business needs.

Example attributes of this infrastructure that would make it agile would be: adaptability in who does what and when among existing and potential partners: adaptability in who tracks that performance: distributed responsibility for handling complaints and researching improvements: a robust mechanism for handling exceptions facilitate open communication.

A more detailed breakdown:

- *Planning Work Breakdown Assignments:* processes concern how the work of the VE is decomposed among the various partners to the benefit of both each partner and the VE.
- *Work Breakdown Responsibilities:* processes concern who is responsible for what work in the VE. The previous group dealt with planning, this deals with performing.
- *Monitoring/Adjusting WBS:* processes concern who in the VE is responsible for monitoring the work distribution once the VE is in operation, and adjusting the assignments as conditions change.
- *Arbitration/Adjudication:* processes concern how complaints are handled and controversies resolved, presumably early in the game.
- *Routine Exception Handling:* processes concern how unplanned exceptions (other than those involving reassignment of responsibilities) are handled.

4.2.6.4 Physical Infrastructure

This infrastructure encompasses processes that are governed by *physical* laws.

- Warehousing/Logistics

Subinfrastructure deals with issues associated with the movement and storage of goods, equipment and personnel.

Example attributes of this infrastructure that would make it agile would be: real-time interoperatable tracking system; location of human and physical assets independent of ownership or paymaster: high speed, low cost of document movement for generation/change (it's primarily a physical *ownership* and movement problem): ability to sustain a high number of *opportunistic* meetings (unplanned encounters and self-directed agendas). This includes surrogates for physical collocation such as electronic communication; redundancy of facilities and network creates lack of dependency.

Deeper breakdown:

- *VE Human Collaboration:* how people gather and interact to support the VE. This includes surrogates for physical collocation such as electronic communication.

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- *VE Product Collaboration:* how various non-human resources of the VE which must, collaborate as if they were collocated, for example as virtual workcells.
- *Customer's Pipeline, Product:* how the flow of components and services which constitute the product of the VE is physically linked to the customer.
- *Customer's Pipeline, People:* how the individual persons in the VE communicate with the customer.
- *Raw Commodities:* how raw materials which feed the VE flow into it.

- Equipment

Subinfrastructure deals with physical resources (including facilities) employed by the VE to accomplish its goals: doing the work as well as creating, sustaining and changing the VE. Agile processes within this infrastructure would be shared by a Flexible Manufacturing infrastructure model.

Example attributes of this infrastructure that would make it agile would be: modular, reconfigurable, flexible, relocatable, maintainable, and scalable equipment, skill sets and team; multiple sources of equipment

More detail:

- *How Modular:* equipment and related processes which support common and standard interfaces so that equipment-related processes can be defined in an encapsulated form as objects or agents. This allows reconfiguration of collections of such processes.
- *How Reconfigurable:* equipment and related processes which individually are reconfigurable to perform a range of functions.
- *How Scalable:* equipment and related processes which can support an increase in load, throughput, or complexity.
- *How Relocatable:* equipment and related processes which can be relocated from one site, cell, or VE partner to another.
- *How Storable:* equipment and related processes which can be easily and cheaply set aside and recovered when needed.

- Physics

Subinfrastructure deals with those processes that are narrowly constrained by only some law of *physics*, for example assembly sequences, or geographic factors that effect materials properties.

Example attributes of this infrastructure that would make it agile would be: lack of dependency on processes that cannot be scaled for physical or time reasons (2.5 micron chips need clean rooms, epoxy curing requires a large autoclave and a set, long curing time): lack of dependency on a raw material's source (not paper mills, aluminum smelting, raisin growing): lack of dependency on a customer's fixed location (not fire stations, congressional lobbying, concrete plants): lack of dependency on physical presence to detect an instant, short-lived need (slogan tee-shirts for demonstrations)

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Greater breakdown:

- *Geographically Limited Processes:* processes that are tied to certain areas. For instance ore smelting is limited to proximity to mines; aircraft servicing is limited to airports.
- *Scale Limited Processes:* processes that are tied to certain physical scales. For example, semiconductor fabrication is highly defined by feature size limits; certain composite wing sections are constrained to the size of curing autoclaves.
- *Attention Limited Processes:* processes which are influencable only if you are in the right time and place. Many market-creation activities (promoting shoes at the Olympics, reporting the news are obvious examples), depend on having alert agents when and where it counts.
- *Time Limited Processes:* processes that are tied to certain physical *time* scales. For example: brewing, farming, servicing life insurance.
- *Accident Limited Processes:* processes that *depend* on unpredictable (or nearly so) happenstance. Examples might be disaster recovery services; or fabrication of jewelry using extremely rare gems. Note: this is a type of process that presumes a competence in agility.

4.2.7 Infrastructure Observations

[Some perspectives on the infrastructures are noted: how they are numbered, some discussion on how they can to be named, noting alternatives, and internal dependencies among them.]

4.2.7.1 Numbering

In most of the discussion above, we've chosen not to include the numbering system because the numbering will confusingly conflict with paragraph numbers. The lifecycle processes form rows in the matrix, the usual form of the model. And the infrastructures form columns. A standard numbering system that has evolved is for lifecycle processes:

- 1. Opportunity Identification
    - 1.1 Opportunity Strategy
    - 1.2 Exposure
    - 1.3 Targeted Marketing
    - 1.4 Search
- 2. Partner Selection
    - 2.1 Partner Qualification
    - 2.2 Partner Performance History
    - 2.3 Partner Search
- 3. Formation
    - 3.1 Vision/Strategy Development
    - 3.2 Partner Criteria and Selection

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- 3.3 Enterprise Metrics
- 3.4 Capitalization
- 3.5 Product Liabilities
- 3.6 Risk/Reward Strategies
- 3.7 Operating Structure
- 3.8 Dissolution

4. Operation
   - 4.1 Performance Measures
   - 4.2 Customer Relations
   - 4.3 Operating Practice
5. Reconfiguration and Dissolution
   - 5.1 Identification of Need
   - 5.2 Residual Liabilities
   - 5.3 Asset/Equity Dispersal

The rows (infrastructures) use an alphabetic scheme. The focus of the metrics project was on infrastructures C and D below, so they have been expanded to a level appropriate for evaluating an agility strategy. Note that at this level, the three *digit* level, the breakdown is domain dependent. The breakdown here is typical of our case study, a conventional defense aerospace supply chain.

- A. Information Infrastructure
- B. Social/Cultural Infrastructure
  - B.a *Social and Psychological Laws*
  - B.b *Community Cultures*
  - B.c *Business Culture*
- C. Legal/Explicit Infrastructure
  - C.a.a Business Processes: *Strategy Development*
  - C.a.b Business Processes: *Supervise Risk/Reward Process*
  - C.a.c Business Processes: *Supervise Engineering Quality*
  - C.a.d Business Processes: *Work Scheduling*
  - C.a.e Business Processes: *Depth of Customer Relations*
  - C.b.a Legal/Regulatory: *Quality Assurance Agreements*
  - C.b.b Legal/Regulatory: *Risk/Reward Contracts*
  - C.b.c Legal/Regulatory: *How VE is Represented*
  - C.b.d Legal/Regulatory: *Assignment of New Technology*
  - C.b.e Legal/Regulatory: *Labor Agreements*
  - C.c.a WorkFlow (Business Plan): *Planning Work Breakdown Assignments*
  - C.c.b WorkFlow (Business Plan): *Work Breakdown Responsibilities*
  - C.c.c WorkFlow (Business Plan): *Monitoring/Adjusting WBS*
  - C.c.d WorkFlow (Business Plan): *Arbitration/Adjudication*
  - C.c.e WorkFlow (Business Plan): *Routine Exception Handling*
- D. Physical Infrastructure
  - D.a.a Warehousing/Logistics: *VE Human Collaboration*

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- D.a.b Warehousing/Logistics: *VE Product Collaboration*
- D.a.c Warehousing/Logistics: *Customer's Pipeline, Product*
- D.a.d Warehousing/Logistics: *Customer's Pipeline, People*
- D.a.e Warehousing/Logistics: *Raw Commodities*
- D.b.a Equipment: *How Modular*
- D.b.b Equipment: *How Scalable*
- D.b.c Equipment: *How Reconfigurable*
- D.b.d Equipment: *How Relocatable*
- D.b.e Equipment: *How Storable*
- D.c.a Physics: *Geographically Limited Processes*
- D.c.b Physics: *Scale Limited Processes*
- D.c.c Physics: *Attention Limited Processes*
- D.c.d Physics: *Time Limited Processes*
- D.c.e Physics: *Accident Limited Processes*

4.2.7.2 Naming

The terms that have been used may possibly be confusing and misleading. *Legal/Explicit* in particular can give the wrong connotation to an infrastructure of rules and policies which incidentally includes laws. It was proposed that these be renamed to more closely express the qualities that discriminate them. If those qualities are *natural* more intuitive, then the names will make sense. In the end, we chose not to change the names, but the considerations help to define the categories.

A proposal was made to rename *Physical* to *Explicit-Physical*. This domain deals with infrastructure issues which are physically real, so have unambiguous, expressible characterizations which include the laws of physics.

Legal/Explicit, under this proposal, might then become *Explicit-Procedural*. What characterizes this infrastructure is the explicit expression of the rules, procedures, and laws involved. It may not be fair to claim that this collection is fully unambiguous, consistent, or internally correct, but it must be expressible. The infrastructure may have non-deterministic mechanisms, whereas the physical mechanisms of the above are presumed to be deterministic.

Both the cases, *Physical* and *Legal/Explicit*, might have some mechanisms that are not controllable (civil laws, physical laws) and some that are (business rules, plant layout).

Continuing the pattern, *Social/Cultural* appears as *Implicit*. It's assumed that some of the dynamics at work are *hardwired* into our genes and that other dynamics are the result of choices and learned behavior. Thus, this infrastructure category involves the balancing of these two types. Which issues are natural and which artificial, and whether this should reflect the difference by being two categories instead of one, are open issues.

It's assumed that although the forces at work are not explicit, their principles can be understood and codified, though perhaps only by induction. Our effort in situation theory helps with understanding the implicit principles.

This leaves the *Information Infrastructure*. It has always been unique in the sense of being the most fundamental. Rather than being the set of computers in an enterprise, this set of mechanisms deals with the ability to represent, integrate in some fashion, and manage the various *representations* involved. There are a host of issues that follow, but the discriminator from the others is simple. They deal with the actual applications, whereas this one deals with the underlying representations.

So the proposal was to replace the terms:

- Physical
- Legal/Explicit
- Social/Cultural, and
- Information Infrastructures,

with:

- Explicit-physical
- Explicit-procedural
- Implicit, and
- Representational Infrastructures.

Ultimately, we decided not to make the name changes. We would have done so if the target audience were academics who could appreciate the more precise terms. But since the user is the decisionmaker, we felt that despite problems, any intuitive aid is a plus.

The four infrastructures may be clean and distinct regarding the tools used to express and manipulate metrics (that remains to be seen), but they are not distinct in the way that decisions will be made. In particular, the four infrastructures are not in a formally *orthogonal*, but in a dependent relationship. Fortunately, the dependency seems to be straightforward and linear.

Each of the four infrastructures inherits some requirements from the preceding one and some representational constraints from the one following. That is, the methods used to represent information in the more explicit ones build on techniques used in the less explicit ones. So, for example, the representation paradigm used in the Legal/Explicit (Explicit-Procedural) domain inherits properties from that used in the Social/Cultural (Implicit) domain.

This issue is important because of the implications for integrating and transporting information across domains. We'd like to have our cake and also eat it: while recognizing that different representation/application paradigms are a fact of life, we'd also like to work with some principles that would apply across the enterprise. The metrics should be as simple as possible, leveraging the enterprise-wide issues as much as possible.

4.2.7.3 Dependencies

We took the infrastructure dependencies a step further, since there are internal dependencies that are generally recognized. For instance, *Business Culture* often affects *Business Processes*. These dependencies are listed below and shown in the figures which follow. They help in selecting the few cells that are key to an agility strategy.

- Social/Cultural Infrastructure
  - *Social and Psychological Laws* is weakly affected by *Business Culture*
  - *Community Cultures* are affected by *Social and Psychological Laws*
  - *Business Culture* is affected by *Community Cultures*
- Legal/Explicit Infrastructure
  - *Business Processes* are affected by *Business Culture and Legal/Regulatory*
  - *Legal/Regulatory* is weakly affected by *Social and Psychological Laws*
  - *WorkFlow* is affected by *Business Processes*
- Physical Infrastructure
  - *Warehousing/Logistics* is affected by *WorkFlow and Physical Laws*
  - *Equipment* is affected by *WorkFlow, Warehousing/Logistics and Physical Laws*
  - *Physical Laws* are not affected by anything

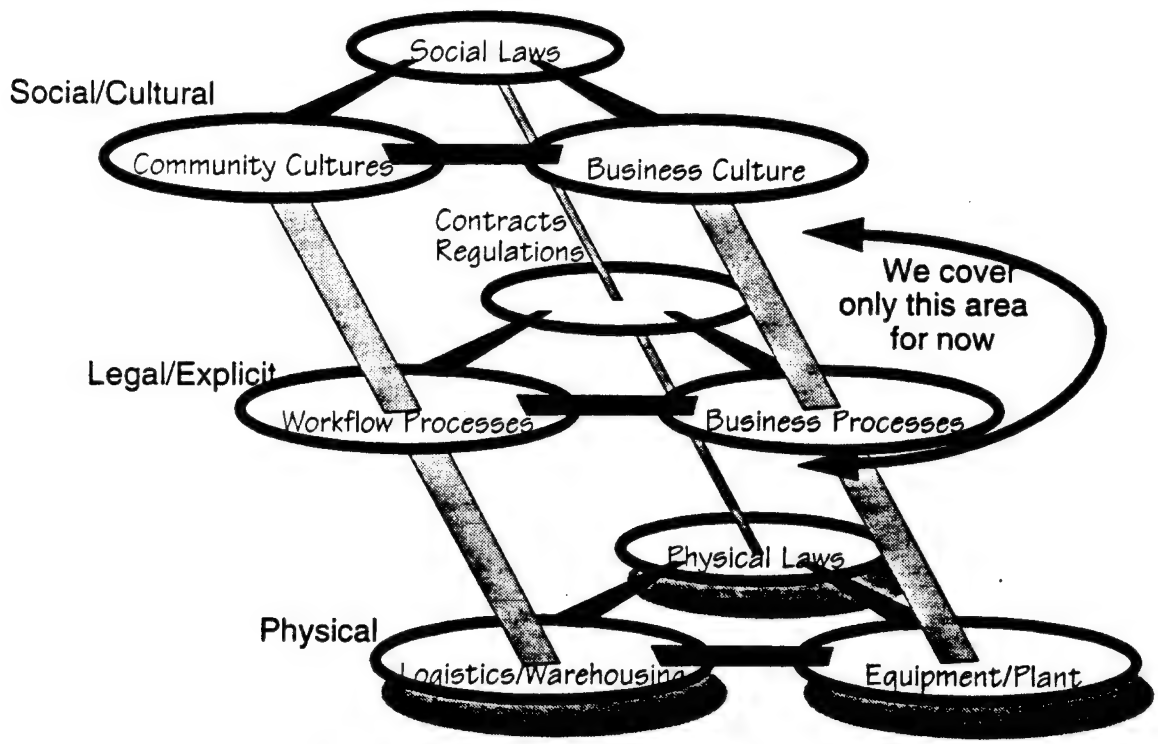

Figure 4-2:Key Infrastructure Breakdowns

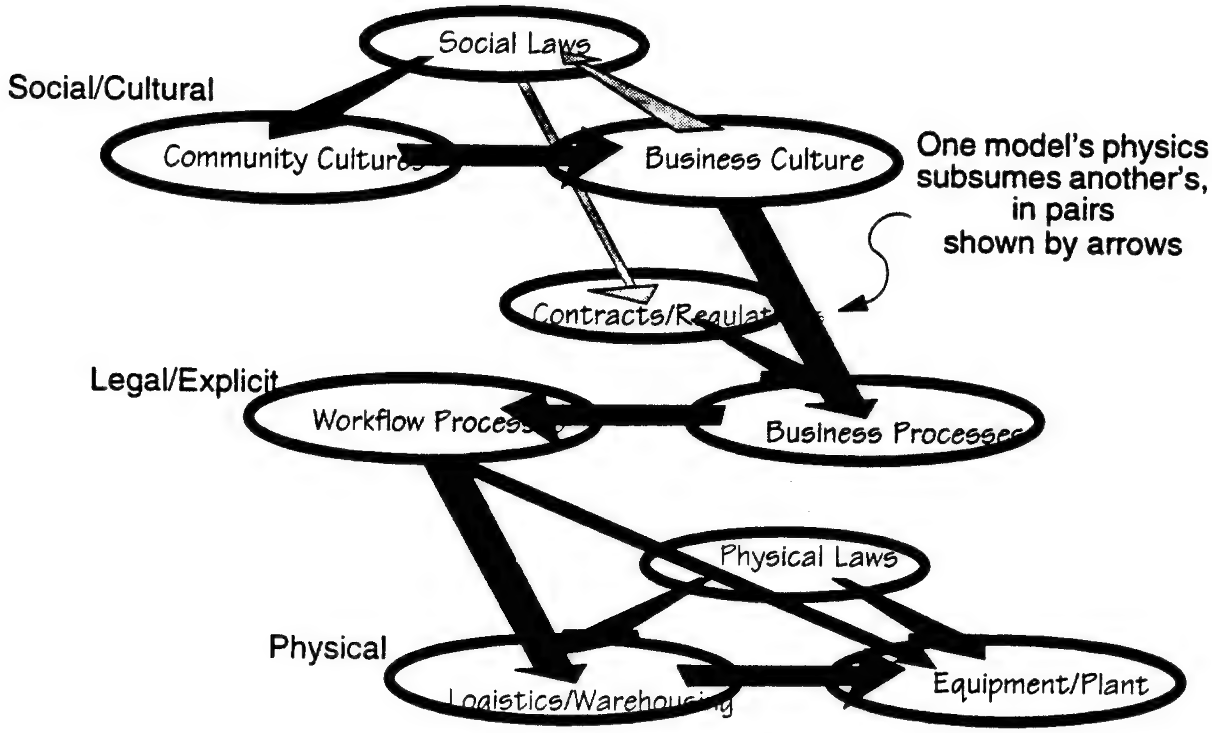

Figure 4-3:Key Dependencies

4.2.8 Example Cells

[The Reference Model is further clarified by giving detailed examples of twenty cells. Each example has three example instances.]

We've found that the best way to describe the AVE Reference Model is to suggest some examples for cells. We've selected twenty example cells, which have been judged high value cells for the defense aerospace case.

	C.a.e Depth of Customer Relations	C.b.b Risk/Reward Contracts	C.c.c Work Breakdown Structure	D.a.a Human Collaboration
1.3 Targeted Market				
2.3 Partner Search				
3.6 Risk/Reward Strategies				
4.1 Performance Metrics				
5.1 Identify Need for Change				

Table 4-1: Specific Cells of Interest

For each of these cells we've given a definition and provided three suggestions. Note that these are not prescriptive; what cells are important, and what is the most agile *entry* in a given cell is directly related to strategic and environmental conditions. And of course, a certain type or extent of agility may not be beneficial to the VE.

4.2.8.1 Row 1.3: Opportunity Identification: Targeted Market and Column C.a.e: Legal/Explicit Infrastructure: Business Processes: Depth of Customer Relations

Cell concerns business processes which support how new markets are identified, and existing markets are served and extended through establishing strong and meaningful relationships with customers.

Examples:

- A business process which sends sales and marketing staff on *prospecting* missions, customer visits to learn what opportunities are nascent.
- VE marketing practices which encourage partners to bring market contacts to

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the VE even though they are outside the existing VE scope.

- Customer focus groups which are convened with the intent of exploring what-if scenarios.

4.2.8.2 Row 1.3: Opportunity Identification: Targeted Market and Column C.b.b: Legal/Explicit Infrastructure: Legal/Regulatory: Risk/Reward Contracts

Cell concerns how partnership contracts are structured within the VE to reward partners for promoting the VE outside of their primary role, possibly penalizing partners in some way for not advancing the VE where it conflicts with their interests.

Examples:

- Contract provisions which provide a *finder's fee* for identifying both promising new market targets and ones that work.
- Provisions that subsidize partners to expand capabilities in such a way that the benefit accrues more to the VE in new markets than to the partner in increased profits.
- Provisions that withhold bonus payments from partners who siphon off new opportunities for themselves at the cost of the VE.

4.2.8.3 Row 1.3: Opportunity Identification: Targeted Market and Column C.c.c: Legal/Explicit Infrastructure: WorkFlow (Business Plan): Work Breakdown Structure

Cell concerns how assigning or reassigning who does what can open new markets.

Examples:

- Processes which recognize that by moving work from one partner to another serves a specific customer's future *Just In Time* workflow requirements to the detriment of the current VE workflow.
- Redundancy in assigning work requirements so that a backup exists in case of problems.
- Choosing a partner for a specific work package not because they are the best in that area, but because they offer a greater spectrum of VE-complementary possibilities.

4.2.8.4 Row 1.3: Opportunity Identification: Targeted Market and Column D.a.a:

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Physical Infrastructure: Warehousing/Logistics: Human Collaboration

Cell concerns the strategies for getting people in the VE together physically (or a virtual substitute) in order to identify, analyze and pursue new VE (and individual) market opportunities.

Examples:

- A central location, suitably designed and furnished, which hosts regular meetings of existing and potential partners for the purpose of market targeting.
- An email discussion group, or a paper memo distribution, that shares substantial information on leads with existing and potential partners.
- A dedicated roving person, perhaps an independent broker, who circulates among partners getting and sharing market ideas.

4.2.8.5 Row 2.3: Partner Selection: Partner Search and Column C.a.e: Legal/Explicit Infrastructure: Business Processes: Depth of Customer Relations

Cell concerns how relationships with existing and future customers are mined to identify best partners.

Examples:

- A business practice which involves the customer in searching for and meaningfully evaluating partners to meet specific needs of those customers which may not have been explicitly identified in the original opportunity scope.
- Creation of an *experience database*, shared with competitors, of positive and negative experiences that a wide variety of customers have had in similar circumstances.
- A VE-subsidized activity-based costing analysis of a customer's enterprise to assure that the VE best benefits the customer's value chain in ways that may not be apparent from the VE's perspective alone.

4.2.8.6 Row 2.3: Partner Selection: Partner Search and Column C.b.b: Legal/ Explicit Infrastructure: Legal/Regulatory: Risk/Reward Contracts

Cell concerns rewards that may go to partners for identifying new partners, even when that works against the original partners' conventional interests.

Examples:

- A broker's fee which shares the cost of savings between the VE and a partner when that partner decreases its role in the VE to the benefit of the VE or the customer.
- A VE-subsidized *risk fund* that pays for studies within partners to explore ways of working with their competitors in precompetitive areas.
- Labor agreements which reward evaluations, and perhaps certification of part-

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ners with whom they have experience.

4.2.8.7 Row 2.3: Partner Selection: Partner Search and Column C.c.c: Legal/Explicit Infrastructure: WorkFlow (Business Plan): Work Breakdown Structure

Cell concerns how it is decided who does what within the VE.

Examples:

- Agreements with the customer that give them insight into the process of and final say over how and to whom the work is assigned within the VE.
- Dynamic *agent systems* that quickly and cheaply support bidding among many warm partners who are competitors who can do the same work.
- A process for creating spin-offs from the VE or partners that have key capabilities that are only available to the VE and successors (defined somehow).

4.2.8.8 Row 2.3: Partner Selection: Partner Search and Column D.a.a: Physical Infrastructure: Warehousing/Logistics: Human Collaboration

Cell concerns support for physical space wherein representatives from potential partners can come to be evaluated.

Examples:

- An *assessment center* for potential partners to evaluate how well they fit in others projected on the team, and how they respond to change within the engineered VE. This presumes that performance on the actual task is known.
- Maintenance of a centralized database of prequalified partner information.
- A regular retreat location where customers, brokers/consultants, and prospective partners explore not what they do, but be aware of what they *might* do.

4.2.8.9 Row 3.6: VE Formation: Risk/Reward Strategies and Column C.a.e: Legal/ Explicit Infrastructure: Business Processes: Depth of Customer Relations

Cell concerns how the relationship with the customer is exploited to incentivize behavior deep within the VE that benefits the customer, the VE and the partners.

Examples:

- Training sessions which increase the awareness throughout the supplier chain of how the VE supports the customer, and how each function results in profit.
- A partner within the VE whose primary mission is to act as advocate for the customer (or the customer's customer), and which provides input to the initial partnering negotiations.
- A *simulation tool* that exercises several models of reward strategies and breakdowns with the intent of optimizing continuing linkage to the customer.

4.2.8.10 Row 3.6: VE Formation: Risk/Reward Strategies and Column C.b.b: Legal/ Explicit Infrastructure: Legal/Regulatory: Risk/Reward Contracts

Cell concerns the actual contract support for the risk/reward strategy.

Examples:

- Contract negotiations for forming the VE are conducted by an outside legal contractor whose remuneration is tied to the success of the VE.
- A major portion of each partner's payments are tied to *shares*, percentages of the VE's profits.
- A major portion of the capitalization of the VE comes from the partners in rough distribution to the profit to each expected.

4.2.8.11 Row 3.6: VE Formation: Risk/Reward Strategies and Column C.c.c: Legal/ Explicit Infrastructure: WorkFlow (Business Plan): Work Breakdown Structure

Cell concerns the linkage between determining who *does* what, and who *gets paid* how much.

Examples:

- A pricing system that is not tied to extra-VE market pricing, but instead special intra-VE value-added analysis.
- A system that accords influence over the management of the VE (controlling votes), based on the value added by each constituent.
- A flexible system for rewarding partners for suggesting ways to improve the work breakdown (and other VE roles).

4.2.8.12 Row 3.6: VE Formation: Risk/Reward Strategies and Column D.a.a: Physical Infrastructure: Warehousing/Logistics: Human Collaboration

Cell concerns how human interaction among VE partners is managed to assure that trust is maintained.

Examples:

- A regular retreat where partners' representatives can not only relax and socialize but also air problems and misunderstandings.
- A dedicated consultant which travels from partner to partner to brief what the other players do and to carry concerns from one to the other, presumably also conducting team-building exercises.
- A partner dedicated to arbitration, using a central database of performance metrics on each of the partners.

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4.2.8.13 Row 4.1: VE Operation: Performance Metrics and Column C.a.e: Legal/

Explicit Infrastructure: Business Processes: Depth of Customer Relations

Cell concerns the method of using customer satisfaction to evaluate how well each activity in the VE is performing.

Examples:

- An *activity evaluation* which determines not only whether each member is doing what was expected, but also the extent to which it adds to customer satisfaction.
- Benchmarking to compare *whatif* changes in the VE to competitors' offerings.
- Quality of life audits to determine whether market forces are optimizing the well-being of the customer and the VE.

4.2.8.14 Row 4.1: VE Operation: Performance Metrics and Column C.b.b: Legal/ Explicit Infrastructure: Legal/Regulatory: Risk/Reward Contracts

Cell concerns the level of connection between partner reward and real-time monitoring of performance.

Examples:

- Quality metrics tied to partner payments.
- Customer-generated agility metrics tied to partner payments.
- Metrics which weight reimbursement for investment based on the level of risk involved.

4.2.8.15 Row 4.1: VE Operation: Performance Metrics and Column C.c.c: Legal/ Explicit Infrastructure: WorkFlow (Business Plan): Work Breakdown Structure

Cell concerns how the work is divided in order to be monitorable by the VE.

Examples:

- A *lingua franca* within the VE which allows each participant to understand the performance if its partners.
- A set of product and corporate responsibility boundaries that corresponds to measurable process boundaries.
- A generic, comprehensive set of performance measures that can be used to advertise and contract for services from a pool of new partners.

4.2.8.16 Row 4.1: VE Operation: Performance Metrics and Column D.a.a: Physical Infrastructure: Warehousing/Logistics: Human Collaboration

Cell concerns how human collaboration within the VE is measured.

Examples:

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- Qualitative measures for the level of quality in collaboration among team members.
- A specific assessment center for evaluating (and improving) intercompany collaborative team functioning.
- Support for extracorporate, *extra-VE* teams, such as labor unions.

4.2.8.17 Row 5.1: VE Reconfiguration/Dissolution: Identify Need for Change and Column C.a.e: Legal/Explicit Infrastructure: Business Processes: Depth of Customer Relations

Cell concerns the way the VE gets indications from the customer that the VE needs to change (or blink out).

Examples:

- Dedicated agents (persons) in key partners whose primary job is sensing the customer for changes in the opportunity which mobilized the VE.
- Agents who deliberately *destabilize* the market in controlled ways to sense and create new trends.
- Processes which examine unrelated markets for analogies which may indicate general technical, economic and social trends.

4.2.8.18 Row 5.1: VE Reconfiguration/Dissolution: Identify Need for Change and Column C.b.b: Legal/Explicit Infrastructure: Legal/Regulatory: Risk/Reward Contracts

Cell concerns how partners get reimbursed for sensing, communicating and acting on the need for change.

Examples:

- A reward pool for agents, perhaps deep in the supply base, who report suspected changes that are later validated.
- An investment pool which subsidizes internal R&D in a partner which could effect the that partner's role, someone else in the VE, or the customer.
- Disincentives for partners which focus on a narrow, inflexible customer need which is susceptible to change.

4.2.8.19 Row 5.1: VE Reconfiguration/Dissolution: Identify Need for Change and Column C.c.c: Legal/Explicit Infrastructure: WorkFlow (Business Plan): Work Breakdown Structure

Cell concerns how the VE is decomposed in a way that eases the identification of change and the change itself.

Examples:

- A work breakdown structure which is designed in such a way to make processes relatively independent; processes and players can be swapped without major change among other partners.
- Work breakdown of VE control functions which makes it difficult for each partner to not be alert to change, for instance by having each process responsible for its own comparative value-added audit.
- Elimination of a dominant prime, so that the roles of leadership is forced into innovative reinventing in order to preserve the frangible institution.

4.2.8.20 Row 5.1: VE Reconfiguration/Dissolution: Identify Need for Change and Column D.a.a: Physical Infrastructure: Warehousing/Logistics: Human Collaboration

Cell concerns how partners interact to identify the need for change and planning for change.

Examples:

- A *simulation center* where partners use role playing to identify future problems in the market, and in external change forces.
- A process where employees are shifted from one partner to another for long periods with the primary goal of cross-fertilizing ideas for improvement.
- Workforce collaborative and educational practices which produce *High Performance Workforces* (that is, those which support a culture likely to drive innovation).

4.3 Best Agile Practice Examples

|The Reference Model was generated in the context of a significant number of case studies. Eight examples are given here.|

The Focus Group created the Reference Model and associated definitions in concert with a major effort in surveying best practices in agility. Although we had extensive involvement in the group, it was essential for us to have something *real* to discuss.

In addition to the important work of helping with the mode discovered a few things:

- Needless to say, there are no cases where an enterprise has deliberately engineered agility into the system. The tools, such as metrics, did not exist, so such engineering was impossible. So we captured agility, even when it was accidental.
- There are no cases that we found where the VE was wholly agile. We captured cases where agility was manifest in some notable area.
- There are no fully Type 1 or 2 VEs. We surveyed relatively conventional VEs.

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- All were agile in either VE formation or operation, but not both.

About fifty sites were identified based on insights from the group and the larger virtual group. These were interviewed by phone and/or email, and nearly twenty were visited. Eight were deemed useful cases for discussion outside the group. Half of these, four, insisted on anonymity. More than half of those surveyed overall had concerns which would have resulted in similar restrictions.

Specific case reports follow:

Name	Type	Sector
Anon Railroad	2	Svc
FlexCell	4	Mfg
Sikorsky	1p	Mfg
Anon Elex Mfr	1	Mfg
Westinghouse		Mfg
Anon Airline	4	Svc
Anon Shipyard	3	Mfg
Taligent	1p	"Mfg"

4.3.1 Anonymous Railroad

[A railroad forms virtual enterprises on behalf of future freight users. How they identify opportunities is novel.]

This anonymous case concerns a major railway. Surveyed was its ability to partner with a potential industrial firm to locate at a site which would be served in perpetuity by the railroad. It is a qualified Type 2 AVE.

The strength of railroads, like local phone and utility suppliers, is built on growth. Some growth comes from increased use from the existing base, but the most important growth comes from new users. With railroads this means attracting certain industries to sites which are or can be served by their rail. In other words, stockholder value can only be increased if other firms, the rails' customers, grow.

This rail company has been remarkably successful in matching sites and firms, thus strongly outpacing its competitors in growing its sustaining base.

The best practices is this case are in the opportunity identification and partner selection. A full-time staff is dedicated to these tasks. They are independent of the traditional sales/marketing staff, and enjoy a high status and priority over resources in the firm.

There appear to be several facets of how these best practices are executed:

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A set of long-lived partnerships have been established to support the needs of the short-term VE partnership. These partners are of two types: those who share the goals of the VE (local utilities, municipal/state economic development authorities, local chambers of commerce, possibly unions), and those that provide supporting analytical and consulting services.

This *team* is entirely opportunity driven.

The rail company employs a staff (which uses consultants) to keep current a collection of knowledge about trends in certain industries which traditionally use rail service. State of the art market prediction tools are employed. In some cases, this mirrors (but is independent of) similar forecasts going on the firms in those sectors. The purpose of these analyses is to anticipate an industrial need which is likely to be served by assets in the rail's geographic area.

The rail company does not wait for a firm to take action on a need, but actively seeks them out with their results. Often when the businesses are approached, they have independently determined the need (opportunity). But sometimes they have not and are surprised, in which case they often welcome the information.

Because the rail line has good operations research skills from its running of the railroad, it has developed good operations research-based tools to keep the focus of expensive analyses narrow and the approaches limited to high payoffs. This is the key to entire endeavor and could form the basis of Opportunity Strategy metrics.

Agility comes into play here. The nature of the tools is two-fold: one *edition* of tools looks at long-lived trends. The other edition is optimized to analyze surprises, to look for new niches opened by the surprise. This latter set is adapted from tools developed by a commodities speculation firm.

One feature of the tools is remarkable. Each analysis needs to have two *faces*: one which shows risk/reward of the core business of the (at this point unknown) manufacturer; and another which shows the risks/rewards to the rail company.

The rail company does not expose itself to a partner until it has been identified by its in-house work. (Of course, there are cases where a *partner* is out looking for a site and calls on the rail company or municipality, but that's another situation.) Hardly anyone, much less the rail company's competition knows the extent of the behind the scenes analysis.

The rail company learned early on to limit its target markets to only those industrial situations where their geographic strengths (supplemented by the efforts of the cities, etc.) are clearly strong. A best practice appears to be that the target market determination is largely made by each partner before introducing themselves. The partner-specific spins on this determination form the basis for all VE decisions which follow.

One winning feature of the evaluation is the weighting in favor of foreign firms who do not yet have US plants, and therefore regional entanglements. Maintaining the capability of addressing this involves having staff or available consultants who can speak several languages (and understand the partner's local business signals).

The same operations research-based metrics from above come to bear on the need for marrying non-U. S. business practice to those of the U. S.

There is no partner search as such. It appears to be a best practice that the search criteria are built into the opportunity strategy and are not an afterthought. In other words, the opportunity analysis determines not only (for example) that a new fertilizer plant can be justified, but also which firm is the strongest to succeed at it.

What results is the formation of temporary VE with the intent of getting the target firm established and operating. Many interesting stories were reported, involving core competencies specific to the occasion. None generic were perceived except the strength of the local VE to handle the unexpected issues thrown at the newcomer. Once that newcomer is established, it begins its normal business, and the VE is dissolved.

Legal agreements are light, and often largely overlooked.

4.3.2 FlexCell

[A successful bidding coalition.]

FlexCell is a collection of small businesses, banded together for collective business development. Their business is focused on small lots of machined/manufactured parts and associated services.

They are a Type 4 AVE, using conventional practices for most of the reference base subcategories with the following exception.

The partners are nearly exclusively drawn from a closed group, geographically limited. Membership in the collaborative is built around decision makers in the firms. Prequalification is achieved by history and trust, incubated by encounter-group like techniques and socialization. The key best practice is the assignment of a full-time person whose goal is build and maintain that trust over several years.

The link is exclusively within the Social/Cultural infrastructure.

This practice leverages local, agriculturally-based values of honesty and constancy. It also appears to depend on a rare, high energy individual.

There does not appear to be an indication for a metric. The metric is binary: if you compromise the trust factor incubated by the group, you are likely to be shunned.

This group is trying to develop some legal infrastructure though a shared financing mechanism, but there is no track record or Legal best practice yet.

4.3.3 Sikorsky

[Capturing key processes for transfer to partners of convenience.]

Sikorsky Aircraft, a $2.3B corporation, manufactures both commercial and military helicopters. The VE effort surveyed here examines how a permanent Type 1 VE, still in creation, is leveraging a specific, valuable best practice.

Sikorsky, as with essentially all helicopter manufacturers, has in the past relied on a stable base of military orders. Recently, that military base has sharply declined and its future is in question. The firm has responded by designing a helicopter with potentially broad appeal to commercial and international users. Sikorsky realizes that they must respond to a price driven market yet still deliver quality products with high performance on time.

This craft, the S-92, is not wholly new, being derived from their successful *Black-Hawk* series. The new design primarily adds internal cabin space and modified subsystems so that the derivatives can be brought to market relatively quickly and inexpensively.

However, a new product requires customers, and in the S-92's case, key customers are international. These international concerns will require that at least their machines are manufactured in their countries in some sort of joint venture. Therefore, Sikorsky is necessarily in the Virtual Enterprise business. Sikorsky is familiar with teaming and has recent experience integrating product and process with Boeing on the Commanche. But partnering with the S-92 partners will be very much more difficult because of cultural and technical barriers as well as the need for speed.

What is novel about this case is a specific infrastructure investment that is being made. This investment will greatly improve the ability to agily form Virtual Enterprises and is a best practice of an early phase of the VE.

The problem is one of transferring key elements of some manufacturing practices to a partner and integrating those with other practices of Sikorsky, who will act as prime contractor. In that role, the prime is responsible for quality throughout the aircraft. Cases in similar (non Sikorsky) situations, has demonstrated that the detailed definition of and integration to processes is a difficult job which has not yet been done well

Sikorsky has an ambitious effort underway to introduce small knowledge bases to key processes associated with manufacturing engineering. *Rule Based Technology* (RBT) is used to create a tool to perform some special, bounded function associated with an engineering process. This tool is usually embedded in the 3-D CAD environment. Therefore it has a dual nature: it is both a part of the process, and contains explicit, expert knowledge about the process.

About two dozen of these *knowledge projects* are underway. Some relate to supervisory or oversight functions, and most concern the relationship among design, manufacturing engineering, and the manufacturing process. Typically, a knowledge project is scoped at 6 months and 2000 hours for the first benefits. The effort is well past the stage where management is identifying isolated problem processes. Now, individual engineering managers are growing the projects into *adjacent* processes so that knowledge about communicating processes is captured.

The most difficult areas are being addressed first. The effect of this preparation is that key processes are being super-modeled in knowledge based tools that can be leveraged for the AVE. Two effects are apparent.

- First, the tools literally replace expertise, usually held by a group of cross-func-

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tional experts. Since the expertise is *packaged*, that expertise can be quickly transferred to a partner in the form of tools. Obviously, the resulting fabric of processes which incorporate these tools will strongly resemble Sikorsky's, making team integration and reconfiguration much easier.

- A second effect is an extension of one well-known benefit of modeling. By making the expertise explicit in the knowledgebase, Sikorsky gains insight into the process itself. This allows for benefits in a number of dimensions. One cogent to Agile Virtual Enterprises is that the boundaries between processes, and their metrics, become more formal and trackable. These boundaries will be essential for fine-grained assignment of the work balance among partners.

Note that the coarse division of the aircraft among partners will be based on largely political factors, not on an informed analysis of the manufacturing processes. It makes the integration of fine-grained processes much more difficult. This is especially so considering that the responsibility (and liability!) for the craft resides with the prime.

Certainly this early investment will reap major payoff as the VEs are formed. It is interesting therefore that none of the investment was justified in terms of the AVE benefits. Instead, a rigorous *return on investment* case is made for each knowledge project with benefits on existing, in-house work within a year. Those cases which have been completed have resulted in substantial savings when considered locally, that is, without consideration to the S-92 and the VE.

The Best Practice here is assigned to Partner Qualification, but could be spread over at least a couple reference base subcategories.

- Operating Structure (in part) covers the processes of harmonizing cultures, integrating processes, and establishing what in this case is the supervisory role of the prime over quality. The Best Practice is in making those three elements explicit and portable before entering into the confusing period of actually establishing the VE.
- Partner Qualification. This case adds something to the Focus Group's understanding of this subcategory. In this case, the partners are selected for reasons which are not primarily based on capability. Thus, Sikorsky assumes some responsibility to make the partners qualified. The greater Sikorsky's ability to insert technology into partners, the greater the pool of potential partners and therefore the larger the number of countries which can be addressed.

We would expect, with further study, to find some leverage for metrics here. The place to look is the boundary of the knowledge project. We noted that these projects are often rescoped to make them larger or smaller, so that they represent a meaningful process module of a handy size.

The case hasn't yet addressed the four infrastructures. We expect that the major impact will be on the cultural infrastructure: the use of these tools by the partner(s) will necessarily bring most of the manufacturing engineering (but not manufacturing) processes into harmony with Sikorsky.

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The Information Infrastructure play is indirect: rule-based representation tools are in a support role, not as a driver. But Sikorsky is finding that legacy systems may be problematic. For instance, the S-92 is based on the BlackHawk, much of which was not exclusively designed using CAD methods. Therefore, a conversion of legacy data to 3D CAD models may be required to fully take advantage of the best practice.

Probably, this practice would only work in a matrixed organization, where functional responsibilities across the company are well defined. The result, in a firm like Sikorsky, is that each Rule Based Technology knowledge project is dual-use, equally applicable to military and commercial aircraft.

Sikorsky managers expect many of these projects to be portable to other industries as well. Chrysler, for example, has a similar Rule Based Technology initiative. Their CAD checker project is being used in 8 other firms, most not in the auto business.

4.3.4 Anonymous Electronics Manufacturer

[Partners are evaluated in part on the potential for differing types of liabilities.]

This case concerns an anonymous large consumer electronics manufacturing firm. (Only certain features of the VE can be discussed.)

The example involves this firm entering into a Type 1 VE in the key best practice, and a Type 2 otherwise.

The background is that many consumer electronics markets require very fast ramp-ups of manufacturing capability to take advantage of a need, a niche, or to round out a product line.

A fairly large, promiscuous base of suppliers exist to help address this need. Some only manufacture for others, and some are firms who manufacture their own brand names in the same markets. In many cases, our firm, and many like it, would job out the entire product, adding only the brand name (and some design).

In the past, the firm would use fairly simple criteria to select partners: cost, and schedule. Quality was an issue, but only insofar as requiring the partner to meet certain minimum standards. Notably, strategic issues have not been a factor; such issues might include selecting a supplier to keep it away from a competitor, or not selecting it because of fear of creating a future competitor.

What's new in how partners are selected now is that liability is becoming an issue.

Two kinds of liability are now considered. The product carries a liability. Generally, the liability is of two types (which overlap). The simple type deals with product failure: the downstream cost of products which fail for reasons not covered by negotiated specifications after the VE is dissolved. The more dangerous product liability is the potential that the product will cause damage, resulting in costly suits or recalls.

Another type of liability is also important: liability associated with the process. Generally this consists of the risk of latent environmental damage, workplace suits (harassment/discrimination), and intellectual property infringements.

This firm now performs analyses on potential partners to evaluate all these liabilities. They are combined with other, traditional measures in selecting partners.

This best practice, therefore, is in the subcategory of Partner Qualification, though it impacts Product Liabilities and Risk/Reward Strategies processes later in the formation process. What's so interesting is that the practice directly employs (actually creates) metrics.

These metrics are quantitative and can be easily converted to dollars. The techniques used were derived from actuarial techniques developed by insurance actuaries. This involves a special methodology for modeling the processes of interest. The processes are captured in this specific way, which often involves field surveys. Then, special analytical tools are used.

A large, historical database (including information from other actuarial domains) is also used.

It's notable that, while the firm sponsored the development of the metric and process, it was developed and is wholly performed by a captive, but independent consulting firm. My understanding of the process is that it would be applicable to a wide variety of AVE applications. But it may be difficult to blast it free, since it is a very valuable competitive tool.

Obviously, the impact is on the legal infrastructure more than the other cases.

4.3.5 Westinghouse

[Partners drive a part of the opportunity identification when is determined by emerging processes.]

The case involves a division of Westinghouse, since sold to Northrop Grumman, that supplies complex electronic products. The dominant customer is the U. S. government. As with many suppliers of complex goods with a large supplier base, Westinghouse has begun to reduce and prequalify its supplier base. Probably, the firm is in the world-class category in how they manage this process, independent of agility.

The best practice of interest to the VE is related to how they take advantage of their supplier base. The sector in which Westinghouse competes is characterized by many bidding situations coupled with a remarkable need for keeping up (or leading with) advanced product and process technologies. In conventional supplier relationships, technology and bidding strategies trickle down to the suppliers, having been determined *at the top*.

Westinghouse, however has well-developed mechanisms to involve their suppliers as partners in both strategic technology planning and competitive bid development.

As the supplier base has narrowed, supplier liaison personnel have increased their scope to include the entire product development cycle. Suppliers are contin-

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ually surveyed for potentially advantageous new skills and processes which might add to the overall competitiveness of the Type 3 VE. Once an opportunity to bid has been identified, the portfolio of new processes is surveyed for advantage.

Therefore, when the bid is developed, the suppliers become involved in a more peer-to-peer way than their competition.

The ability of a supplier to work with Westinghouse in this closer manner is one of the criteria used in searching, evaluating and prequalifying partners.

4.3.6 Anonymous Airline

[A novel way of fencing off a partner's relationships with competitors for a special project.]

This case is an anonymous airline. The VE effort surveyed how a Type 4 VE is employed to provide market guidance using partners which are also partnered with competitors.

Domestic airlines have lost a lot of money in the past few years, and this airline has been heavily hit. Most airlines are substantially constrained in the changes they can make in costs and price. Costs can be squeezed somewhat, but only to a point. The price charged is a matter of a game largely unconnected to what to the product costs. One airline has to meet another's price, while lowering prices on other routes offensively.

In this environment, airlines are desperate to differentiate themselves, to create brand loyalty. The frequent, business traveler is the target. To this end, all major airlines have frequent traveler programs. All of these programs partner with essentially the same set of hotel and rental car corporations, in a near-Type 4 VE.

However, this airline was able to use its partnership to develop market information which it will use to enhance its competitive position, while preventing similar information to flow back to its competitors. The result is a marketing strategy which could make a big difference in saving the airline by creating greater business traveler loyalty. (The specific strategy is not mentioned here.)

How this was accomplished constitutes a best practice.

Each frequent traveler point program, in air, car and hotel industries is fully computerized. The typical business traveler is assiduous in assuring his points are tracked, so gathering information on who went to what kinds of places and how often is an easy task. Each partner sells that information, usually for a discount against the traveler's benefits.

This airline wanted to go much further, to do some targeted marketing research to identify an expected unmet need that they could address better than the competition. They wanted to get this information without direct airline-to-traveler interviews for various reasons. At the same time, they realized that car and hotel firms routinely identify and address needs similar to those they sought.

The question was: how to use their partners (primarily hotel) to reprocess old information and collect new information without letting that information fall into

the hands of their competitors. The situation is similar to many shared intellectual property problems in design/manufacturing VEs.

The Risk/Reward Strategies subcategory was supposed to address ownership of newly generated intellectual property. But it fails to address the situation when that property originates in the second-tier partners, but takes on added value through the VE. This case indicated an expansion of the definition of that subcategory.

In this case, the airline negotiated some very sensitive legal instruments. Individuals (by name) in each organization were *compartmentalized*: each could only work in the context of the VE and its successor, not to work with a competitor for specified number of years.

The hotel partners were limited to two who compete in different markets to avoid friction and confusion. These hotel partners were granted preference in co-operative marketing when the new service begins, in addition to some financial recompense.

Some physical separation of workers and records was required, as well as some co-location. (Unknown to the airline this mirrors a solution to similar intellectual property problems in the defense and aerospace industries.)

The legal agreements treated the employees (for the sake of intellectual property) as if they were employed by a joint venture. A line of supervision, populated by the partners was established just for these issues (policy, arbitration). No other joint venture management structure was created; all else was managed under conventional buyer-supplier frameworks.

While the legal and physical infrastructures were affected, the information and cultural infrastructures were not.

The VE was truly agile in the sense of disassembling after the need was met, to be replaced by a more conventional relationship. However, the effort went so well that the arrangement may be revived in the future for more market intelligence needs.

Relevance to metrics exists in the nature of the legal documents we were told, but we were not able to examine those agreements. It was explained that statistical methods were used to determine what percentage (or portion) of the intellectual property was generated new within the VE and which originated in a partner. We got the impression that these methods were derived from activity-based costing methods, meaning the cost and not the value of the information formed the basis of the metric.

4.3.7 Anonymous Shipyard

[A process plan for a new business area is manufactured as if it were a product of the old process plan.]

This case is an anonymous shipyard, which until recently was mainly involved in U. S. Navy work. The VE effort surveyed here is how a Type 3 VE was used to bring core competencies to bring to bear and accomplish a switch to commercial business.

The firm surveyed once was largely a commercial yard. But for the last few decades, no new-ship commercial construction had occurred, following a sorry national trend. The Reagan buildup kept the yard busy until recently. A combination of predicable, and largely non-predicable (political reversals) forced this firm to seek an agile introduction into commercial work.

What is novel about this case is how they leveraged a pool of suppliers for government work into a VE to address commercial work.

Building a naval ship is an interesting business. The shipyard acts as a prime contractor for a weapon system, and a large supply chain is involved. This supply chain changes from ship to ship, but consists of a limited, fairly well-connected community. Many of the practices involved in installing and integrating a component on a ship are co-developed between the prime and the supplier.

In this case, the prime had lost its corporate knowledge concerning commercial practices. But that knowledge largely existed, in a distributed fashion, in the supplier base. If the yard failed, the supplier base would suffer. So the prime/supplier relationships were supplemented by a VE to transfer commercial skills to the prime.

In normal commercial yards, the job of estimating the job (building an ship) is relatively disconnected from planning and building the ship. In military work, the two are more closely connected. The process plan is sketched out for the estimate, then fleshed out for the actual building. This provided leverage for the prime to commit to a supplier base, conditional on getting the work. Then those suppliers came in and helped develop the process plan (supporting the estimate), working side-by-side with the yard's planners.

The VE was opportunistic, based only on the one buy. Risks were shared, a radical change for the supplier base, but their later marketing expenses were reduced.

In the first case, the buy was successful, and commercial ships will be built by the yard, the first VE reverting to a traditional supplier/prime relationship. Plans are underway to use this mechanism to identify and address unusual and niche market commercial work. The idea is that they can address these new and unusual situations faster and cheaper by relying on their suppliers to help develop the at-risk process plans for confident bids.

There is a lesson here for military primes who feel hampered by an onerous up-front planning culture. It can be turned into a mechanism to bring new, commercial skills from the supplier base into the organization via a VE.

The Best Practice here focuses on Operating Structure. Besides the novelty of the idea, the yard developed a way to coordinate the cacophony of bottom-up planning. (They were used to a more top-down philosophy.)

The development of the bidding-level process plan was seen as a manufacturing task in itself. A process plan for that (a *metaprocess* plan?) was developed with identification of who would come in when, for roughly how long, to help develop what piece of the shipbuilding plan. This idea of planning for the creation of a

working structure for a VE is powerful one, which we were not able to expand beyond the scope of the shipbuilding sector. But it seems generally applicable.

We would expect, with further study, to find some leverage for metrics here.

Conventional supplier/chain legal infrastructure was used with the exception of early selection for at risk assistance.

Physical infrastructure was important, with facilitated temporary collocation being essential. Socialization was moderately encouraged. Participants think that more of this would help next time, since the one time pressure could not be sustained. Information infrastructure was not a factor, in the sense of requiring new capability.

4.3.8 Taligent

[Risk and Reward strategies make a software developer change a few times in midstream.]

Taligent is a joint venture, a permanent Type 1 VE, whose charter is to provide a radical improvement in the ability to develop and use software in enterprises. The company is developing a next generation object oriented (OO) application system that is portable across all major desktop hardware and operating system environments. It was originally formed by IBM and Apple nearly three years ago.

Several major changes have been made since its formation. A new major partner, Hewlett-Packard was brought into the VE. The development reference platform was changed from Apple Macintosh 68K to IBM AIX RS6000, a technical enhancement in response to developer requirements. The mission of the company was changed, based on customer feedback, from deploying a single integrated OO environment to providing both a portable application system that rides on many operating systems and a separate OO operating system.

The focus of this case is how Taligent has been able to listen to and respond to their customers, the three investors, as partners and outside customers, while juggling the realities of competitive versus precompetitive issues.

Three internal policies contribute to this ability. Taligent's investors and partners must cultivate a trust relationship with Taligent while they also compete with each other. Taligent's workforce will collaborate closely with a respective partner in either the shared domain or various proprietary domains. For Taligent to proceed, it must scrupulously maintain the confidentiality of the information shared by its partners. No single set of procedures could cover all the conditions which arise in unexpected ways. The VE's solution is to provide leadership by example from above. A strong, ethical tone is set by the senior management and permeates the corporate culture which is unique.

We were not able to gather anecdotes to illustrate the practice. But numerous discussions with the sponsors underscored how prominent and visible this feature is in the corporate culture. It greatly eases the potential for mistrust and allows focus on the mission.

4.3.9 Recent Events

[Events since the case studies underscore the fact that agility in one dimension is no guarantee in another. A surprising number of the example best practices have failed.]

The best practices studies are only two years old, but already major changes have occurred. It is illustrative to note that the agility we discovered was not adequate to address the major changes that occurred. The change that actually took place differed from that targeted by the recorded agility.

- The railroad's competitors were not so successful improving their own territory. So they have sought to grow stockholder value by acquiring other railroads. This has forced our company to follow suit. The rules of the game changed.
- The division of Westinghouse we surveyed was apparently unexpectedly acquired by Northrop Grumman and its supply chain practices are turning more conventional as it merges.
- Costs in the airline business have changed and threatening mega-mergers have appeared. Labor costs have forced our surveyed company to abandon the improvement we tracked.
- The shipyard we cited competes commercially with international firms and is hampered by exchange rates. Losses on the first commercial effort are high, and more work has not been attracted.
- The internet radically changed the market for operating systems. Many of the fundamental assumptions of Taligent no longer fit. Taligent has been dissolved.

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5 Modeling by Communicative Acts

[The metrics depend on breaking Reference Model entries down further into communicative acts. An introduction to communicative acts is given in this section.]

In addition to the Reference Model, the metrics depend on a few fundamental foundations, one being the use of a canonical decomposition of processes. Such a decomposition is required because we look at the *structure* of processes rather than the details of their content and meaning. Taking this approach both highlights the dynamic couplings of interest within the VE and avoids the comparatively high cost of semantic (meaning-based) modeling.

But what decomposition to use? The bewildering variety of process modeling approaches is only an indication of the variety of theoretical approaches we could take. One goal of the project was discover the best approach.

We settled on one that is close enough to the mainstream that a great body of existing science could be inherited. On the other hand, the approach is still under development and freshly incorporates new thinking about agency and effect. What's still being uncovered are in areas unimportant to the metrics per se, but which support our emerging work in soft modeling.

5.1 The Emergent Systems Influence

[One reason for communicative acts is to exploit emergent behavior, such as that exploited by simulations, or as appears with autonomous agents.]

The goal of our project was to help decisionmakers design agile enterprise systems. In the steady state, a strategic planner knows what there is to work with and what has to be done, together with other constraints. But the agility space is different. One doesn't know what all the threats or opportunities are, what has to be done.

One can determine only some general features of what to plan for in the future. So how does one design systems to respond to unknown situations? The answer is often to design systems that are self-adapting, that respond to major change perhaps without even seeing it as such.

Our immediate goal is to reveal metrics. But we know that metrics are only a starting point. Planners will want to not only know how agile a process/system is, but also how to improve it. It's only responsible of us to choose a representation that supports this need.

Breaking things down by behavior defines *agents* in a way that agent systems theorists can directly use to model, predict and validate emergent behavior. *Emergent behavior* in this context is behavior that the system automatically assumes because of the way it is constituted. The extent to which it adapts, the cost of adaptation (extended from our metrics) and whether the result is desirable or not are all results for which we are laying groundwork.

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Key concepts are:

- *Emergent behavior* as the adaptive mechanism which constitutes agility
- *Agents* as the units which exhibit this behavior. For our purposes, an agent is

something, usually someone, who does work. We define what work is of interest through the Reference Model

- *Speech acts*, or Communicative acts, which is the exchange of information that allows agents to collaborate

Breaking processes, in particular process cells of the Reference Model, into speech acts is key to identifying and evaluating the adaptability of the enterprise.

5.2 The Need for Federatable Executables

[We think that the approach could in the future support self-organizing enterprise integration strategies.]

Regardless of whether one invests in the emergent systems paradigm, important planning and control systems are computerized. It seldom occurs that all of an enterprise's knowledge, models and code are well integrated. This becomes less true as business models involving many partners become more useful, as in an agile supply chain. The state of integration reaches a disastrous state in the Agile Virtual Enterprise.

What the AVE needs is a collection of methods and tools which will allow it to quickly and cheaply federate systems and knowledge among players regardless of whether there are appropriate standards in use. Developing general federating principles for the AVE is well outside of the scope of the project; however, history shows that when a relationship is formed, and collaboration is desired, metrics form the basis for framing that collaboration. Integration is only needed to support collaborative goals. Thus, there is an intimate relationship between metrics and integrating infrastructure.

We need to be sensitive to these issues; we cannot simply devise a strategy in ignorance of its context if it is becomes useful. Our focus on speech acts supports the most promising approach to this federation problem. The approach identifies the agents and certain (epistemological and ontological) principles of how they communicate. Awareness of the context which other agents use allows an agent to adapt its communicative act appropriately to effect federation.

Others feel this way; this speech act approach forms the basis of the Knowledge Query and Manipulation Language (KQML) resulting from significant work in *multi-agent systems* under the DARPA-sponsored Knowledge Sharing Initiative.

5.3 Multiple Representations

[Even within the metrics approach, we support a version of self-organizing integration through federation of our own internal models.]

Similarly, we need to practice federation *within* the enterprise's *normal* representations, because users have different needs and want different presentations. Users in this case may be humans who want to see and understand, humans who want to relay information to an external analysis, or applications which directly access the format.

There is a need for four representations:

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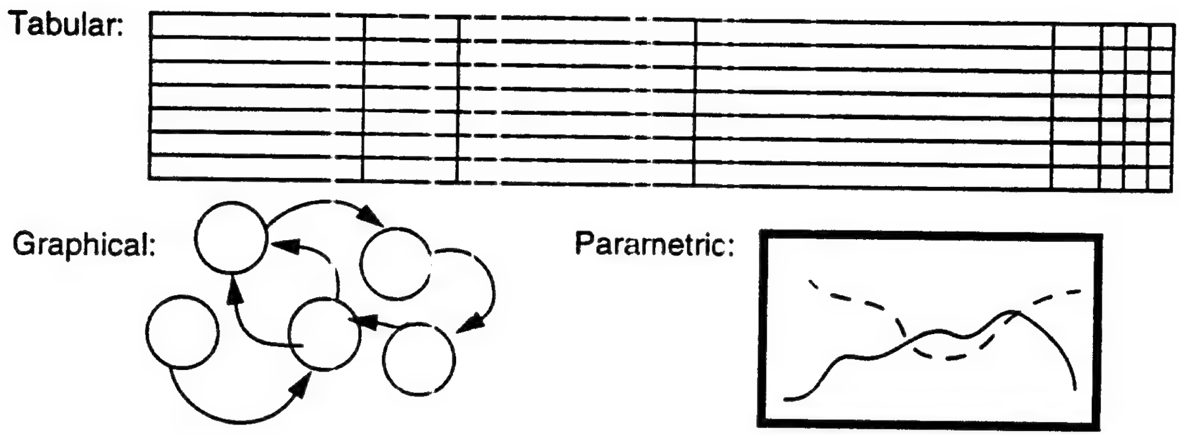
- A *Tabular* (or field or spreadsheet) representation: We've found this type of representation to be the most accessible to non-professional modelers, our target audience. In part, this is because it's a necessarily two-dimensional, ordered means of entering and recovering data elements common to paper and screen layouts. The familiarity is because this is how databases deal with information: each *row*, (the way we present it) is an instance, each *column* is a data type. The accessibility is because each entry is distinctly bounded and cleanly defined. The cells in our spreadsheet view map from our AVE Reference Model.
- A *Graphical* representation: However, when looking at a process as a system, one needs a representation that conveys the whole picture and key relationships at once. We've chosen a specific graphical representation called a Dooley Graph which is described in some detail below. It is not a graphic logical notation for robust modeling, as one would find within a modeling methodology. Instead, it is a simple presentation (nodes and arrow) which reveals the structural elements of interest to us regarding how the agents are coupled.
- A *Parametric* representation: This consists of numbers and arithmetic relationships among them. It is essential that this model exist. We believe that few users will consider agility in a vacuum. They will be dealing with the costs and benefits of agility within the context of other business factors, and the common way for these to be balanced is as numbers in parametric models, usually as dollars in spreadsheets. If we cannot present a format for this process, the agility metrics cannot enter the mainstream.
- A *Sentential* representation: While many of our initial users will deal only with the parametric model, a whole new class of planning tools are emerging. These tools understand much of the underlying logic of processes and systems, differing from the tools which work from mere numbers. Formal statements, or sentences are required, statements about processes or related dynamics. The nature of this representation, its capabilities, and possible future uses are the topic of the part on Soft Modeling.

These are not just different views of the same data; they are different models. Some algorithmic transformation is required. The sentential is the most complete, while our parametric model has the least information, containing only our specific arithmetic results. These four models would ideally be federated within an agility planning tool.

Federation would allow a user to explore options in any representation and see the effects in another. The likeliest of these scenarios would be for a planner to enter a collection of real or possible processes in the tabular form, seeing the numbers which indicate agility of each process and the total system. Not liking the number, the planner may choose to look at the graphic format and ask what changes would make the process or system more agile (or equally agile at a lower cost). The tool may call externally using the sentential format, getting back results which show differing graphs and their respective numbers.

The part dealing with Tool Strategies explores this in depth.



Sentential: S ⊨<<acts, p, t, m. <seeks, Or, Ot, 1>, g, 1>>

Figure 5-1:Four Different Representations

5.4 Formal Foundations

[Communicative acts helps us lay a rigorous foundation.]

Everything we do has to have a foundation that is rigorous. One reason is that we simply cannot support the useful agenda that we lay out above. Another is that business planning is not a casual affair. Where an auditable logic chain is sought, we should be able to deliver.

Agility is a radical idea; the engineering of enterprises to be agile systems in a predictable manner is even more so. Conventional foundations can only take us so far. We cannot afford to create new science, so a strategy was taken to leverage solid science from other domains into this new one where appropriate. Some terms and binding needed to be developed.

Among the insights that were integrated, one is central to the method: modeling processes in the enterprise as *conversations*, then measuring the complexity of the resulting structure.

5.4.1 The Conversation Metaphor

[The approach allows us to see processes in terms of conversations of communicative acts.]

Our representation utilizes a *conversation* metaphor. The basic idea is that agility is a matter of dynamic coupling. How processes are coupled is by information transfer. A convenient way to see one specific information transfer is to view it as an *utterance*, which is originated by a single agent and directed at one or more agents. A collection of related utterances is a conversation. Each process in the en-

terprise involves a conversation which reveals its information structure, the dynamics of how it is coupled internally and with other processes.

There's a fairly deep epistemological reason why this approach works for us, which we won't examine in depth. But a simple explanation is that we are interested in the dynamics of collaboration, what some information values are within a complete *system*. By defining our primitives as single acts, originating from single actors, we reveal a topology of the collaboration within that system.

This representation has a number of benefits:

- It reveals what we need, requiring the minimum (read: lowest cost) data collection
- It can be directly used for simulation, each actor specification being expressible as executable code
- As a result, it can specify and predict (some) behavior in non-deterministic systems, and reveal emergent behavior
- The metaphor is intuitive in that many of the harder processes one models are business processes; here conversations map literally to what is said.

Its primary disadvantage is that it is unfamiliar to business analysts and planners, our target audience. The case study evaluates the costs associated with this unfamiliarity.

5.5 Background of Speech Acts

[A few words on some background and related definitions.]

A common sense view of a simple statement is that it contains information and is either true or false. Much has been built around this idea and we now have elaborate and useful notions of the truth, information content and meaning of statements. Generally, the approach keeps the idea of statements which communicate information separate from the work that goes on at either end.

This is seen also in the conventional distinction in computer science between data and programs. Data is information that is often shared among machines and humans. Programs on the other hand are relatively immobile, often seen as *black boxes*.

But another view merges the two classes. An *utterance* by someone is part of the work that is being done, a rather significant part of the overall work if the activity is highly collaborative. Formal thinking of this view has been around for 35 years or so [AUST62].

This idea has fortunately been elaborated by the agent community which began within the artificial intelligence community and since has flourished while generally AI has languished. A substantial percentage of the key sponsorship for this work was by the Advanced Research Projects Agency, one example of which is KQML, as we've noted [CL95]. This represents a decade of refinement of the ideas.

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Hereafter, for consistency, we'll use the term *utterance* where we have also used *communicative act*, and *statement*. A coherent collection of utterances will be a *conversation*. The types of utterances are *performatives*.

5.5.1 Relevance to Agility

[A small section on communication as the dynamic coupling which some define as agility.]

Before we get into details, let's review what we are doing and why. Agility is concerned not with everything that occurs in an enterprise. It's concerned with how things are coupled, how they interact, and how readily that coupling can respond in a beneficial way. In this, we are following the thinking of Ken Preiss [PGN96].

That coupling is the same, if we are careful, as the set of utterances among agents within an enterprise. The Reference Model helps us with this care. By adopting the foundations of agent theory, we'll be able to have a formal basis for looking at the nature of the coupling.

5.6 A Candidate Dynamics of Speech Acts

[The essentials of speech acts are given here.]

(Information in this section was contributed by Van Parunak of the Industrial Technology Institute.)

Utterances are of different types and this is important. The type of utterance that says:

"Can you paint a widget tomorrow?"

is different from

"Painting a widget tomorrow will cost eight dollars,"

and

"I painted your widget."

The nature of the what is intended is different, and what is required as following utterances changes.

If the goal is to paint widgets, then the first utterance, the query, requires a response, which implies a different type of coupling than the others which are more informational. The different types of utterances are called *performatives*, meaning loosely the different forms of performing work.

Many recent process modeling methods and indexing strategies use this technique of defining performatives. Also, much of the work in the Collaboration Theory area, such as the work at MIT [MCLP93] is close in its philosophy.

Major differences are in how many performatives there are, and what constitutes a useful primitive set. KQML [FFMM94] defines 42 performatives, but there has been discussion that many are ambiguous and redundant. Cohen [CL95] suggests a much simpler approach which introduces the notion of a hierarchy and keeps performatives few and atomic. We've adopted this approach.

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5.6.1 Speech Acts

[The specific types, performatives, of speech (communicative) acts are defined.]

The figure shows the basic types. All acts are presumed to be attempts to accomplish something, so the top of the hierarchy is attempt. All acts are subtypes of *attempt*.

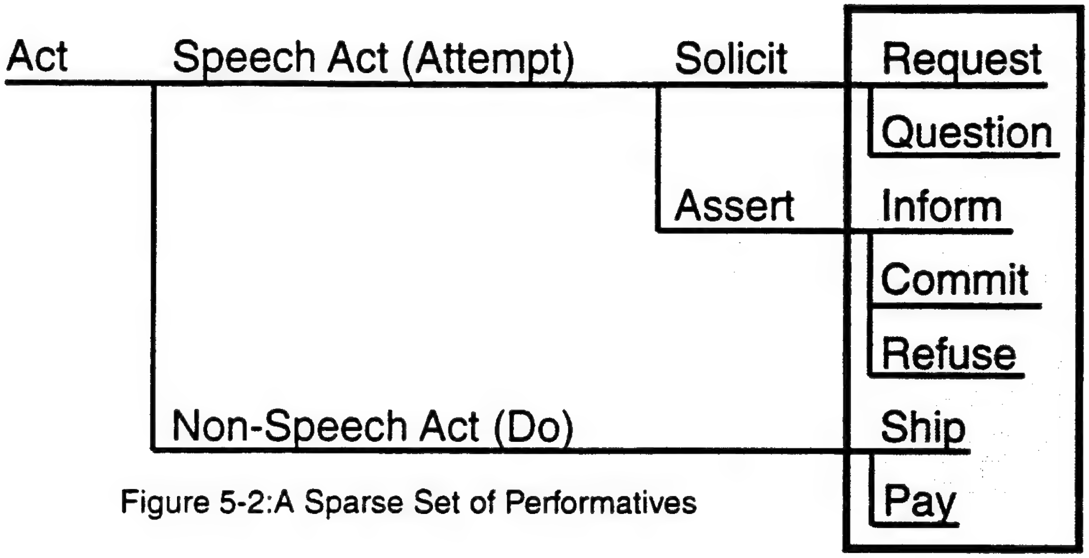

Figure 5-2:A Sparse Set of Performatives

- Solicit: A *solicit* is an *attempt* by a sender to achieve mutual benefit with an addressee. The sender wants the addressee to do something which the sender wants done. The sender defines both what is done and what constitutes completion.
  - Question: A *question* solicits the addressee to *inform* (see below) the sender of some proposition.
  - Request: A *request* solicits the addressee to *commit* (see below) to the sender concerning some action.
- Assert: An assert is an *attempt* by a sender to achieve mutual benefit with an addressee. The sender wants the addressee to believe the *asserted* statement.
  - Inform: An *inform* is an *assert* (an attempt) to get the addressee to believe the content.
  - Commit: A *commit* is an *assert* that the sender has adopted a persistent goal to achieve something relative to the addressee's desires.
  - Refuse: A *refuse* is an *assert* that the sender has not adopted a persistent goal to achieve something relative to the addressee's desires.

There is some work done which is not associated with speech. In the general case, these performatives are many, and difficult to define. Fortunately for us, our strategy makes this part of the problem trivial.

Our scope deals with for-profit business enterprises; we assume that every partner and every process adds value to a goal of creating wealth. What is important is that each process has a cost and it adds value, that's all. So we add two non-speech acts to our performative vocabulary.

- Ship: A *ship* is the transfer of value sender has (perhaps partially) executed some portion of the action promised in an earlier *commit* and a *request* that the addressee *pay*.
- Pay: A *pay* is the transfer of wealth between the sender and the addressee. In some contexts, implies an *assert* that the addressee agrees that the sender has (perhaps partially) executed the action promised in an earlier *commit*.

Needless to say, we can come up with innumerable combinations and special cases of these performatives, as we in fact do in everyday life. For instance, there is could be a type parallel to assert called *command* where the control over the content is with the addressee's desires rather than the sender.

Or one could, for example, construct something called *propose*, composed of an inform of the sender's willingness to take some action on specified terms with a *request* that the addresses *request* this action of the sender. But for the metrics, we insist on this atomic breakdown because it is simple, complete, and gives us a neutral basis for comparisons among processes and systems.

However, we note here that these atomic performatives can be composed to theoretically map to any formally based modeling method based on information exchange. We expect that within certain applications the addition of composed items may emerge as either an aid for interpreting, or as a path to mapping from established models.

5.6.2 Sequential Relations

[The rules for combining acts. These are used later in calculating the Dooley Graph.]

Another component of the theory deals with the sequential relationships among performatives that constitute a conversation. For some time, *reply* and *resolution* have been considered the basis of repartee [LONG76].

Van Parunak [PARU96a][PARU96][PARU96c] proposes that two others, *response* and *completion*, will also be useful. The four together establish relationships among the agents which we will exploit both in creating a graphical representation, and in calculating the metrics. Each of the four is discussed below, the order is from most *connected* to least.

5.6.2.1 Respond

It follows from the definition of a conversation that each utterance, except the first, responds to a previous one. The response linkage is the fundamental binding

which constitutes a conversation in the larger sense; this also is true in the more limited sense we use of a conversation bounded as a process within an enterprise.

An utterance (2) responds to another (1) if:

- (1) was received,
- (1) *caused* (2), (further investigation of cause being taken up in our work on Soft Mathematics), and
- There is no other prior series of utterances which (could have) caused (2). Essentially this means that (1) was the first utterance to be received that could have caused (2).

It is necessary that the utterance one responds to be addressed to it; but it is not necessary that the response go back along the same path. The response could, and often does, involve another party. So if A sent an utterance to B, B could respond to that by sending an utterance to C. But B couldn't respond if A's utterance had been to C. A single utterance can respond to multiple preceding utterances.

5.6.2.2 Reply

Reply is different than respond. Not every utterance after the first is a response. Respond denotes more of a trigger, while reply concerns the *answer* utterance that is triggered. An utterance (2) is a reply to another (1) if:

- (1) was received
- One of the addressees of (1) is the sender of (2)
- The addressee of (2) is the sender of (1)
- (2) is the most recent response from that addressee to (1). This condition simply means that the most direct responses are the only one we recognize, not responses through intermediaries.

It is possible for replies to differ from responses. A could send an utterance (1) to B and C; then B could send an utterance to A. In this case (2) could be both a reply and a response to (1). Then C could send an utterance (3) to A that is triggered by (2). In this case, (3) is a response to (2) and a reply to (1).

5.6.2.3 Resolve

Resolve is a subset of reply. Some utterances presume a reply in the same way that in normal speech a question presumes an answer. This is a result of an utterance controlling some part of the conversation, and the resolve breaks down or completes that temporary control.

A solicit not only communicates a mental state, but also proposes rules for how the next steps of the conversation will proceed. A reply can accept or ignore those rules.

The sender of these kinds of utterances establishes the ground rules for the resolution and thence directs to some extent the flow of collaborative information. Since we presume that our conversation is a process which is engineered to ac-

complish a certain task, this temporal control is important. Presented with this type of control, an addressee can defer resolution, say in order to discover more about the context or other agents. Tracking resolution helps illuminate these dynamics.

We'll revisit this below.

Only some of our performatives can be resolved:

- An appropriate *inform* resolves a *question*, and
- An appropriate *refuse*, *commit*, or non-speech act (*ship*, *pay*) resolves a *request*.

Note that if an utterance has several addressees, it can have that many resolutions.

It also should be noted here that the whole theory is still being refined, and where new uses and context are discovered, changes may be made. For instance, it may be useful in modeling soft processes (those governed by social/psychological laws) to introduce new relations which track how the addressee chooses to deal with this imposed control. What strategy is used and why (assent, defer, ignore, assert) may be important as the scope of the metrics grows (see second order and soft modeling). But this is sufficient for the scope of the project.

5.6.2.4 Complete

Completion is similar to resolve in a way. Where the resolve mechanism captures how the conversation is controlled, the complete mechanism tracks control over the actual work which is the point of the conversation (process).

When one agent commits to do something, it is an important event in the conversation. It's the work that gets done within the bounds of the players that we've constrained in our reference model. Details of that work don't show themselves in the conversation, but how the conversation exerts control over the work does.

Only *commits* can be completed. When a party commits, they assume certain things about the environment, which is another way that constraints are composed over the conversation. But as we've noted this time, the target is not the form of the conversation, but the nature of the work.

A commit can be completed by any act.

Resolve and complete are important to us because they capture the two methods by which agents control the conversation (process) toward a goal. The complexity of those control mechanisms relates to the process's adaptability, hence its agility.

5.6.3 An Example

[An example of a process to speech act model is given. The Dooley Graph is introduced.]

Consider the table below. This shows a simple process at the level of complexity we'll find in a cell of our Reference Model, at the same level as the example of the overview. The process modeled is simple: A prime contractor (*A*) has suppliers (*B*,

C and *D*); the prime needs 50 widgets by next Thursday. We model the process by a specific *instance* which has all of the features of interest. The prime advertises, gets and commits to less than what it wants; changes its mind when it discovers that it can get what it wants; and ends up not getting what it wants so has to take corrective action. Finally, it pays.

Sequence	Sender	Receiver	Utterance	Speech Act	Responds to	Replies to	Resolves	Completes
1	A	B, D, C	Please send me 50 widgets at your catalog price by next Thursday	Request				
2	B	C	Are you bidding on A's RFQ?	Question	1			
3	C	B	Yes, I am	Inform	2	2	2	
4	B	A	I no bid	Refuse	3	1	1	
5	C	A	How about 40 widgets at catalog price by next Friday?	Inform, Request	1	1		
6	A	C	Please send me 40 widgets at catalog price by next Friday	Request	5	5	5	
7	C	A	I plan to send you 40 widgets at catalog price by next Friday	Commit	6	6	6	
8	D	A	I plan to send you 50 widgets at catalog price by next Thursday	Commit	1	1	1	
9	A	C	I've found a better supplier, and am not relying on your Commit	Assert	7,8	7		
10	C	A	I am abandoning my Commit	Refuse	9	9		7
11	D	A	Here are your widgets. Please pay me	Ship	1	1		8
12	A	D	You are five short. Please send the difference	Assert, Request	11	11		
13	D	A	Here are five more widgets, Please pay me.	Ship	12	12	12	
13	A	D	Here's your moola	Pay	13	13	13	

Table 5-1: Breakdown of an Example Process

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We would have selected this instance of the process to capture all of the important features of the process that bear on the agility analysis of interest. Suppose that the type of agility we're evaluating is the ability to uncommit from one supplier when a more adequate one appears.

There would be one conversation like this for each cell of the Reference Model, possibly different conversations for differing strategies or agility-defined conditions of change.

The table has a column for each of the sequential relations: respond, reply, resolve and complete. Each row in the table is a specific *utterance*; it's one and only one of the performatives.

Note how each relation works. *Respond* is pretty intuitive. Reply is pretty much the same as respond in most cases. But see utterance 4 where we've created a situation where it's different. *B* doesn't like to compete with *C* because they know they are lying cheating scum, so *B* asks C if they are bidding and gets an affirmative. So *B* tells the prime in 4 that they are *no bidding*. Utterance 4 was triggered by (*responds* to) 3, but is a *response* to 1. It also *resolves* 1, since that's the end of party *B* for now.

The rest of the relationships are pretty straightforward. The figure shows the overlap of the relationships for the example.

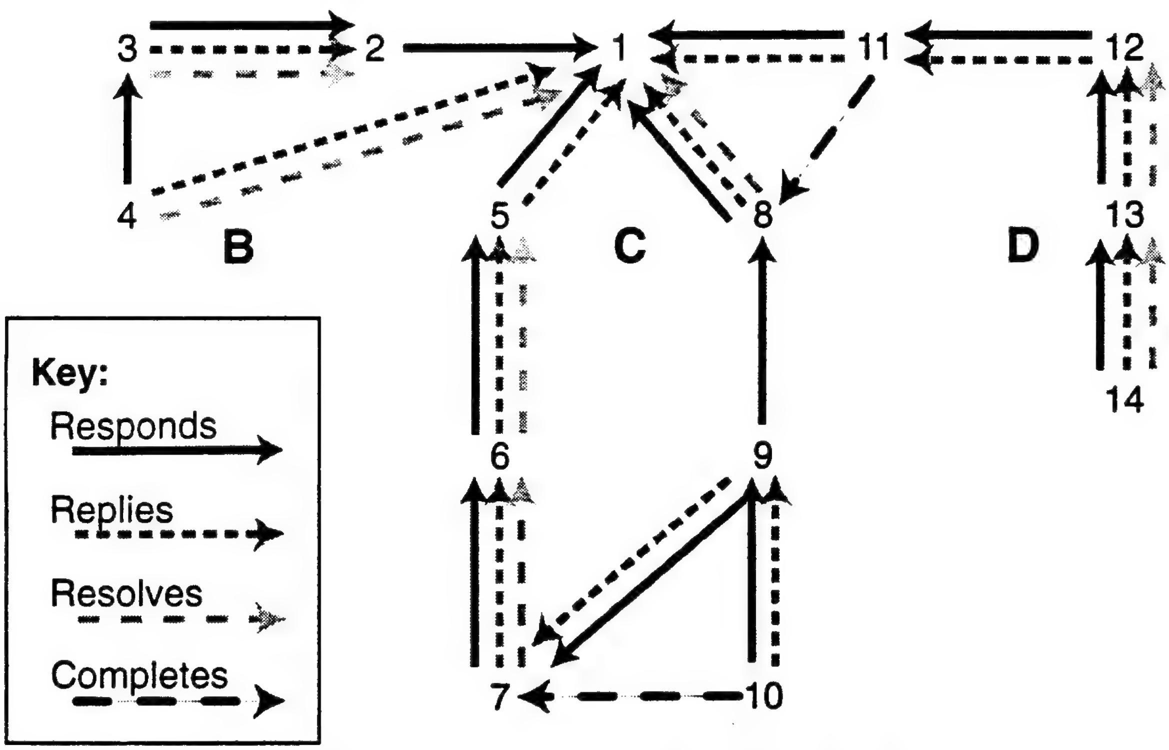

Figure 5-3:The Example's Combined Relationships

There are several ways of graphically representing the example conversation. We want our graphical representation to reveal the specific complexity of the con-

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versation in terms of the features that are costly to both execute and adapt. This graphical form is called a *Dooley Graph*, after the person who first described it.

To introduce Dooley Graphs, we suggest the idea of *states*. In this view, all of the players in the enterprise (*A*, *B*, *C* and *D*) collectively form a state machine. Winograd and Flores [WF88] developed the idea of a state machine that would use performatives of the type described above. A version of their proposal adjusted to Parunak's formalized performatives is shown below. (The Flores version of this has

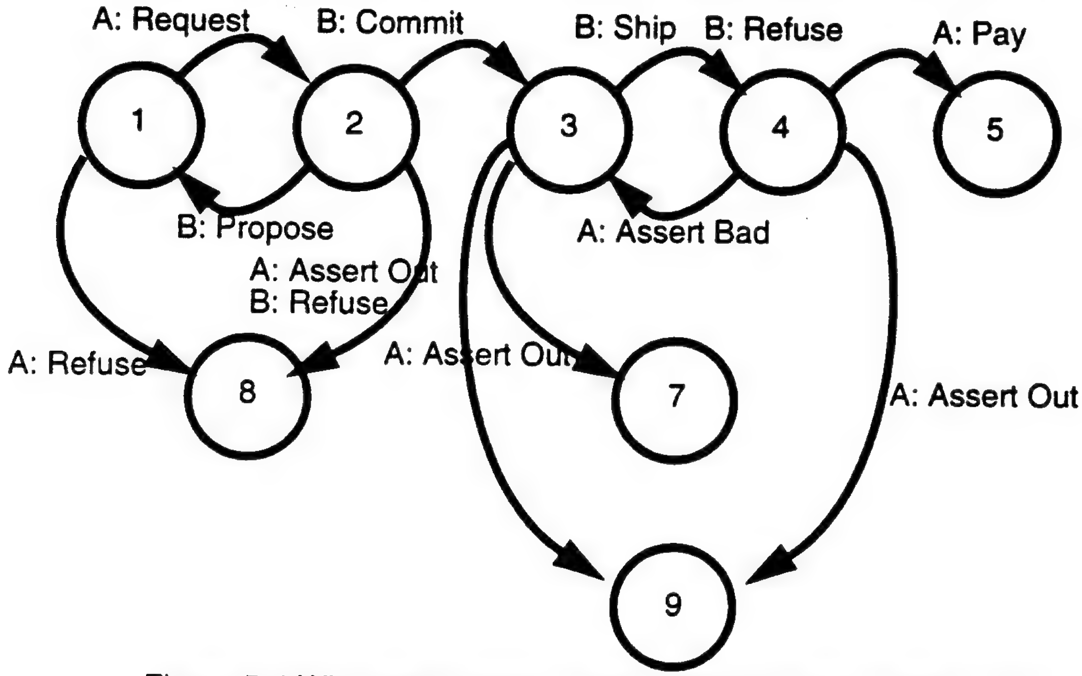

Figure 5-4:Winograd/Flores Model with Formalized Performatives

been successfully commercialized by Action Technologies, and has been validated in useful business contexts).

A Dooley Graph combines the qualities of *states* and *utterances* into one representation, showing both the work to *support* or *move* the conversation (the utterance component) and the work *effected by* the conversation (the state component). It is a simple node diagram, consisting of nodes, or circles and links or arrows. As a hybrid, speakers can occupy more than one node, depending on the state of the conversation. The Dooley Graph of the example is shown below.

See how Party *A* is in two nodes. *A1* is the role *A* plays in a first part of the conversation, advertising and eventually buying widgets. *A2* is a second part of the conversation which involves the commitment for an incomplete purchase and later cancellation of that purchase. The process of which this is an instance has additional complexity to be able to support these additional roles of *A* and *C*. The Dooley Graph reveals these roles.

The method for creating a Dooley Graph is not intuitively obvious; it is the only link in the process that is not, so we have created a prototype application, Pomegranate, and associated class libraries to do so automatically. The algorithm itself is described in Part 4.

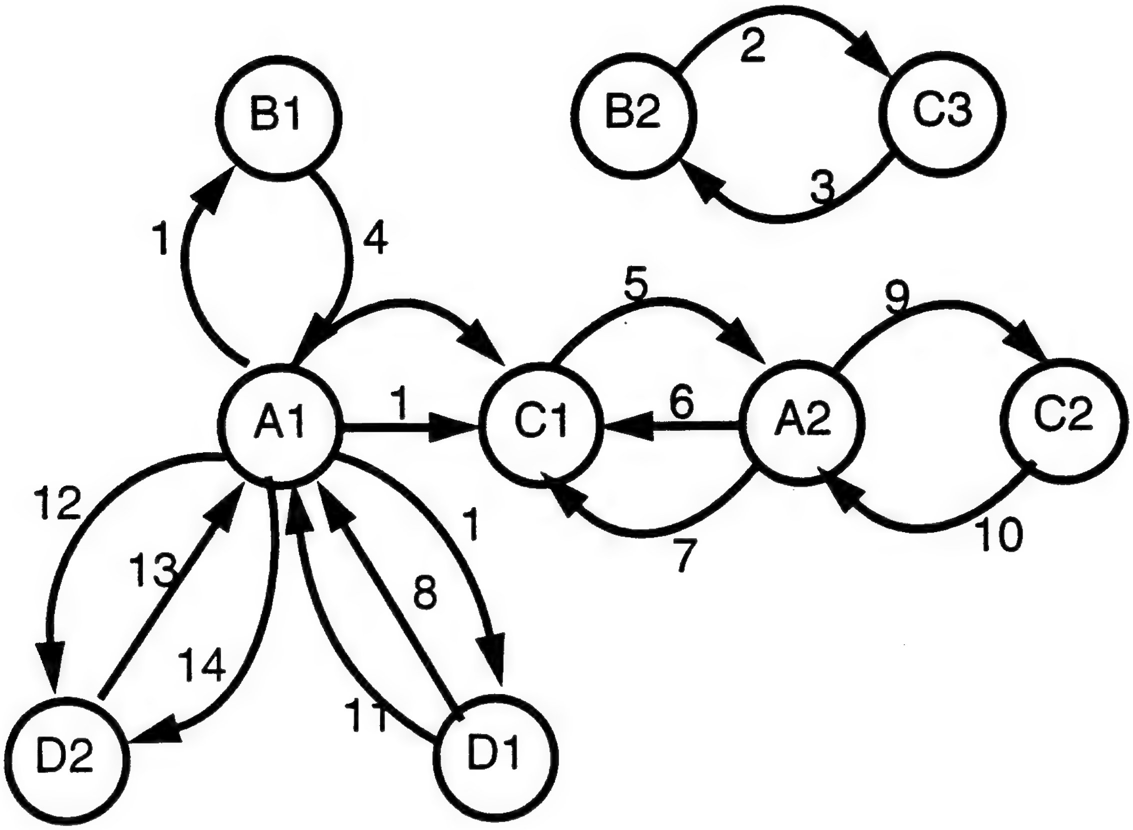

Figure 5-5:The Example's Dooley Graph

6 Agile Strategic Planning

[The metrics' approach assumes a strategy exists. Since there are no known tools for agility planning, we created one as a side project. It is described here.]

This section suggests a technique to feed the decomposition of the enterprise into processes to be instanced by conversations. It is the result of work performed by the AVE Focus Group, Sandia Labs, and the Automation and Robotics Research Institute

Businesses already have tools to support strategic planning to lower cost, increase quality and decrease time to market. Agility is another, albeit new and different, factor that pro-active managers will use in designing the future of their organizations. A central issue is how to create a strategy that has the most beneficial balance of agility with other qualities. Such decisions have a life cycle. And at the end of the planning life cycle, we have the situation where a strategy has been created, and the questions are what decisions are the correct ones to support that strategy, to attain the desired agility. Our metrics support *this* end of strategic planning.

But there is an earlier phase, where strategic ideas are generated and evaluated. This section deals with the generation of novel, advantageous strategies through strategic brainstorming. Other methods will have to concern themselves with the evaluation of those ideas through simulations and associated evaluation.

The method we propose is sensitive to agility. Agility is important in situations where change is assumed, whether that change is something that merely happens or is change that has been instigated by the Virtual Enterprise (VE). Most strategic planning methods assume continuity, their worth depending on the accuracy of uniformly extrapolating from prior, *real*, experience. Again, we see that agility is a radical new idea; new methods must be developed to support it. Although the brainstorming method outlined here is designed to accommodate agility, we believe it to be useful for generating novel strategies across the board.

There are two key ideas in the brainstorming method, the idea of memes and the associated idea of underlying perspectives or principles. We'll briefly introduce those two ideas, immediately below and in Part 3. We suggest that these ideas be hosted in a role playing activity, because that is a well established productive technique where the core ideas are strong. Finally, we add certain *triggers* that analysis of the Dooley Graphs shows

6.1 Memes

[The brainstorming method depends on harnessing irrepressible trends in groups. A handy way to describe these trends is as memes. So a brief introduction to memes is given.]

Certain patterns in the environment seem to pop up over and over again. Have you ever passed someone humming a tune and found yourself humming it all day? These things spread by being passed from host to host, as jokes are from person to person. They act almost like *viruses*, these ideas, pieces of information, and memories, spreading and replicating almost as if they were acting intelligently.

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Moreover, they adapt as conditions warrant; a Chuck Berry guitar riff will promulgate itself in dozens of transmuted ways in successive popular music.

And there are ideas that take on a life of their own, like property ownership, civil liberty, or human rights. The latter two are modern ideas, and the idea of real estate ownership (in the sense that one can sell land as they sell an object) has only a somewhat longer pedigree. It is hard to imagine the eons of human thinking that transpired before these ideas *caught on*. But it was so.

So powerful are these ideas that it is very difficult for historians to get a perspective on actions and motives before they appeared. What is taken as rational thought itself seems to change. The point for us is that as obvious as these ideas are today--or perhaps so obvious that we sometimes ignore them--it would have been almost impossible to predict their appearance, understand their content, and appreciate the resulting changes in the world.

No one would claim that ideas like these are themselves intelligent entities in the way that humans are. Nor does it make sense to see the passing of an idea from one person to another as an intelligent act on the part of the idea (as opposed to the humans involved). But when viewed at a high level in aggregate, intellectual tokens (ideas, musical themes, languages) do seem to act in some ways intelligently.

Such ideas act intelligently in the same way that an ant colony or beehive, when seen collectively, seems to act intelligently. The intelligence is like that ascribed to agents of disease, the behavior of which is studied by epidemiologists, or to genes. Individual varieties of genes can be said to collectively exhibit intelligence, using life forms merely as a vector, a host in their drive to maximize benefit to themselves. Benefit to the hosts over time may coincide with the gene's interests, or it may not.

Much of modern evolutionary thinking (that of constructive evolution) is based on this idea of genes as autonomous, fine-grained agents with collective intelligence, intelligence meaning the ability to adapt to enhance certain goals, in other words, to be *agile*. This is a powerful idea, certain genes acting agily as a learning organization. The idea is so useful that an evolutionary scientist, Richard Dawkins, extended it in 1976 [DAWK76][DAWK96] from genetic entities (biology-based memory) to apply to intelligence-based entities. Such entities include songs, ideas, and the like which are based on memory in the mind or the mind's external stores (books, records, computer memory...).

Dawkins coined the term *Meme* for this kind of self-replicating entity. This coining exemplifies the idea of turning the conventional relationship of (active) actor and (passive) participant on its head, thus:

> "A hen is just an egg's strategy for making another egg."

The idea of memes has itself become a powerful meme, and the idea has found wide use in the artificial intelligence community and in studies of cognition and complexity. We submit the concept as one of the bases for this structured brainstorming method.

A more detailed discussion of memes is spread through Part 3.

6.2 Relevance to Brainstorming

[Why memes may be helpful in predicting enterprise agility.]

In particular, we want to understand what makes a meme tick sufficiently well in order to look at novel future alternatives. By understanding what makes memes catch on, we get closer to understanding the general shape of unexpected change, at least those changes that are humanly driven. The AVE Focus Group's survey indicated that these are the most important, and dangerous to businesses.

When we get to *tactical* agility, we consider the VE as a collection of agents which are dynamically coupled. We concern ourselves with which agents are the best to add or to take away from the VE, for certain agility goals. More importantly, we are interested in understanding and engineering the coupling that dynamically binds those agents. For the case of strategic brainstorming, we'll define the agents differently, as *memes*.

If we are brainstorming a Type 2 VE --in which we have a collection of memes (meaning capabilities) and are brainstorming for an opportunity in which to use them--we'll want to understand the natural tendencies of the memes and the logical directions in which they will go. This is different than evaluating core competencies of the VE in a static manner and evaluating opportunities; instead, you track the meme equivalent. The result is as if you were seeing how the existing core competencies naturally want to evolve and were looking for an opportunity somewhere on that track.

For brainstorming a Type 1 VE--in which we create a hypothetical opportunity and then brainstorm for the correct recipe for a VE which will suit that opportunity--the situation becomes more complex than the above (Type 2 VE) example and also more interesting. Here, you want to develop a meme aggregation that has a natural learning path which will take it in the direction of the opportunity and that has the natural ability to adjust as the opportunity adjusts. The situation is complex because, unlike genetic evolution, you have some freedom to choose partners and engineer the dynamic coupling among them.

A few characteristics of memes are important to AVE brainstorming:

- Memes can be categorized according to their domain of influence, and that decomposition is the same as the infrastructure categorization we've developed. Memes associated with contract law have effect only in that domain; similarly in business practices. We have an example of each, A Key Difference: The Engineering Paradigm and The Role of Common Law.
- Those examples show another characteristic as well, that memes can be grouped into higher classes. The French engineering meme concerned with business practices and the Code meme which deals with legal issues both are part of a higher level class of memes, at some level a *meme-class*. In this French engineering/code case, it's a class that forces a centralized, top-down control of processes.

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- The more robust memes settle into a system by creating a balance with a complementary meme, creating (or following) a simple symmetry. In our example, the English engineering meme was balanced by the French one; the *common law* meme opposed by the code law. This is even more evident at the meme-class level. So *centralized* control systems are opposed in a system, of, say, human society, by a *decentralized* control system, with special cases appearing in law and engineering.
- We submit that all memes (of interest to the AVE) fall under a few basic categories of meme-class. We'll present the four basic sets of meme-classes in the section below.
- Identification of memes in a system is an art, is highly subjective, and often produces results that are trivial or worse--complex but without providing insight. It's much easier to start with a meme-class and develop or discover a specific meme than the other way around.

To review: the idea behind our metrics is that by understanding the processes in AVEs, we can measure their ability to adapt. In order to have productive brainstorming, you need to have a similar understanding of processes, how they adapt and learn in your system. We find that in complex systems a useful way of understanding how processes or agents adapt is by understanding memes. Furthermore, memes themselves have underlying principles, which we've called meme-classes. Useful brainstorming can leverage these relationships by understanding the principles underlying the memes and especially the fact that each meme-class has a dual, an opposite or complement.

6.3 Basic Underlying Principles/Controversies

[We describe a specific taxonomy of memes that can be leveraged for agility brainstorming.]

Here are the *four complementary pairs of meme-classes* which we think form a complete basis for memes in AVEs and which can be used to create a *structured controversy* method for brainstorming.

A disclaimer: work presented in other chapters has a more thorough formal underpinning than here. In particular, the work on abstraction that is novel to the metrics' quantification has a formal basis in category theory; the social modeling relies on situation theory; and the infrastructure and communicative act parsing relies on long established organizational and information theories.

The work of this section is drawn from the history of philosophy and from some working ideas that have been refined through empirical work by the AVE Focus Group. It has not, so far, been thoroughly investigated. But we commend it here because it seems right, it works, and it fills a need in agile planning for which there is no comparably apt technique.

The four basic controversies are:

- 1. Realism versus Phenomenalism
- 2. Intrinsic versus Random Order

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- 3. Evolution versus Revolution
- 4. Centralized versus Distributed Control

These four are fully symmetrical (meaning only that each constitutes a complementary pair, and that any grouping of two complement the remaining two). One would strongly expect to find such symmetry in any sufficiently clean basic disposition of principles. The figure shows the symmetries, see the Soft Mathematics Case Study for a French/English Breakdown and Part 4 for relevance to the current

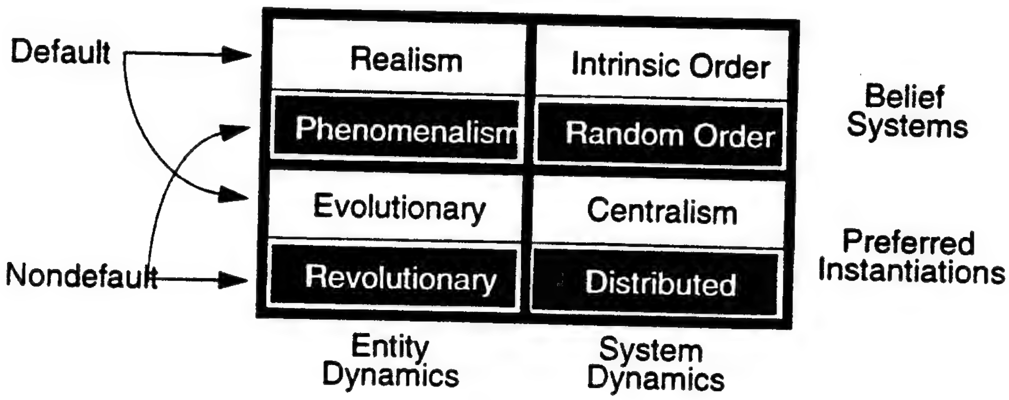

Figure 6-1:Key Meme-Classes

problem in the defense world.

The first two pairs of meme-classes are, relatively speaking, more fundamental than the others. They deal with *belief* systems, with how people believe the world works, and with the characteristics of the fundamental laws of nature. The second two are underlying ways in which the world is *instanced*, how it exists, using those laws.

The first and the third relate to the dynamics of *entities*, what constitutes being, and the second and fourth reflect controversies about the dynamics of *being*, how systems are formed and interact,

Each of the four, of course, denote a primitive controversy, that is, two classes of opposing principles around which many types of ideas can be formed and self-sustaining as memes. The first listed perspective in of each of the four controversies tend to go together; it is more consistent, for instance, for someone who holds realism as a belief to also believe in intrinsic order, evolution, and centralized control, than to take any of the opposite choices along with any of these.

Each of the four are described below. It may be of interest to observe that the institutional default familiar to most businesses within in Western civilization (as well, not just incidentally, as the Abrahamic religions, Judaism, Christianity and Islam) is based on the first choice in each of these meme-classes (realism, intrinsic order, and so on).

6.3.1 Realism versus Phenomenalism

[Whether one believes in a universal clockmaker of some kind or whether the clock invents itself.]

Realism is illustrated in the belief that a tree does make a sound in the woods even if unheard, and, more generally, that the woods exist independent of any need for human existence. The world is real, and humans experience it. Some humans, because of individual differences, may experience it differently, but reality is out there, immutable. The notion of absolute truth follows nicely from this. Truth reflects reality. A scientist who works under this belief believes that it is the role of a scientist to discover and understand the truths of this reality.

Phenomenalism is the group of beliefs that the world we encounter is a collection of ordered experiences. Among diverse observers, we may share some consensus about those experiences as truth, and diverge on the actual nature of the world in other ways. Because we can never encounter the *real* world, only sensory phenomena, reality as an independent state is either moot or unknowable. A scientist working under this system strives toward inventing new ways of explaining phenomena to expand the class of shared consensus. How the scientist communicates and explains is in a sense more important here than what is explained.

Each of these views contain a great many ideas, some of which have a very long tradition. Many memes are spawned and take on their own lives, strengthened in an important way by its complement. Essentially all philosophical discourse uses memes from this class.

As a cogent example, suppose you are brainstorming early in the game of our missile AVE example. The problem you are examining is

"What kind of product strategy is best for us?"

(We've picked a mundane example because of its illustrative value and because of the leverage we get by keying off of the tactical example. After addressing this question, the missile prime might brainstorm on how best to support that strategy through an AVE. A simulation would validate/modify the approach, resulting in the input for the metrics.

Realists might hold that the way that the world works is set, that there is a real, strong idea of a better missile design and a less good one. Their brainstorming could be limited to the context of that reality, trying to understand and negotiate it.

Phenomenalists, on the other hand, could believe that a missile is a product, that its worth is in meeting customer requirements, and that there is no basic good design outside of that context. Since the context is one of how the customer sees the world, they would try to analyze not the world of design, but the world of the customer's predilections, foibles, concerns and inner drives. They might also assume that the customer's world view differs fundamentally from the prime's.

6.3.2 Intrinsic versus Random Order

[Whether the behavior of the clock is a result of design (extrinsic or intrinsic), or an accident of nature.]

Some hold a belief that the world is a clockworks; moreover, that it is a single clockwork system. It all makes sense at some basic level, and laws at work in one area are part of the same script as laws that work in another. This is the class of views that are under the belief systems of *intrinsic order*.

A contrasting view asserts that the fact that we have scientific laws which work does not imply that the world has a single, inner logic. Much of the world is a result of *accidents*--many of the physical constants for instance. So while we've been inventive enough to determine some local order in the cosmos, underlying it all is a higher order of chaotic system. (We've used the term *random order* here for historical reasons; the more formal term would be chaotic order which is an order. Randomness is the lack of order.)

Our missile brainstormers, if they are taking the former position might have views about economics, politics, and society that presume that the laws of design and the laws of business and the laws of good intention are all congruent. What's good for Hughes is good for the U. S. and the world. Well motivated engineers will make better products, and that's good for business, good for the prime. In the large, the system works.

Their contrarians, taking the other option (favoring random order), would hold that what's good for the prime may not be directly and completely good for the customer (the U. S., or part of it anyway); also that there are many areas where competing forces are at work between, say, best design and corporate goals. These brainstormers will be struggling with finding the correct balance of these competing forces--a game of compromise.

It is easy to see how the two groups would gravitate to radically differing product strategies.

6.3.3 Evolution versus Revolution

[Whether new clocks emerge incrementally or in major, disruptive spurts.]

The root of the ideas that we class as *evolutionary* is intuitively understandable. Adherents to this collection of ideas would hold that the law of cause and effect is apparent in every process. Sometimes a small modification in cause produces wide modification in effect, but the function is still apparent. The key discriminator of this class is the belief that any outcome can be predicted if enough causal factors are known.

The opposite hand holds the belief that most every important process in the world has characteristic events where some instability is reached and basic causal conditions are changed. The important, defining element of the process is not the periods of relative stability between punctuations where change is predictable and gradual. Instead, what matters are the periods where many important things change.

In our imaginary brainstorming session, the evolutionists might concern themselves with, say, a product that will provide (a considerable) advantage over the competition, by better understanding and exploiting the currently applicable

rules. The revolutionaries might focus on how to create a product that changes the rules to their advantage.

6.3.4 Centralized versus Distributed Control

[Whether someone central determines the hour, or we reach it by consensus.]

The easiest to grasp controversy of all pits the paradigm of *central* control against that of decentralized or *distributed* control. This (fourth) class and the previous (third) class are not controversies about how the world works, but about preferred ways that the world instances. For both of these, this and the prior one, there are many examples in nature.

In animals, a centralized control system is a mammal with a brain and nervous system. A decentralized example is a bee colony. In U. S. government, central laws and taxes come from Washington, decentralized laws and taxes from innumerable state capitals and town/city halls.

The representative of central thinking will look to a product that leverages the strength of the prime as a prime, so that the prime as a prime is made stronger. The decentralized-minded brainstormer may seize upon a more peer-to-peer AVE based strategy in assembling the portfolio of product options.

6.4 Role Playing

[How to employ the controversies described above in a structured role playing context.]

To the insights noted above, we'll add two techniques. The first is tried and true, that of *role playing*. The second is a way to identify process tendencies by playing with Dooley Graphs. Dooley Graphs were discussed in the previous section.

To perform your structured controversy brainstorming, you'll want to assemble a small group of people, less than ten. Ideally, these will be motivated, alert persons from diverse backgrounds. No prior skills are required beyond minimal group skills, but it's obviously necessary that they be familiar with whatever domain you are brainstorming.

You'll divide these people into two groups in different combinations throughout the exercise. You should have a person present who is in neither group and acts as recorder, since the ideas will come hot and heavy; the best ideas will not be apparent at the time and will have to be identified on reflection. How the group is divided is important, as you'll see.

You should also have a facilitator who is familiar with the method and who can set up the problem, This person will also guide the discussion and insure that players stay in character. The session begins by the facilitator explaining (in about 30 minutes) three things:

- What the method is all about, at the highest level. The discussion on memes can be omitted, rather focusing on the idea of getting new perspectives by looking at situations by taking a new basic slant in a structured controversy.
- What the four basic *religious* principles are and what each controversy is in

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each of the principles. (Since the basic positions of course sometimes do indeed reflect various participants' accustomed religious positions, and since traditional arguments about politics and religion, per se, are not the matters of most interest in these brainstorming sessions, we suggest that the facilitator place no moral emphasis on such terms as *religion* or *God* or *atheism*. Instead of relying on religious and political terms, the facilitator may prefer more neutral labels such as *world views* and *presuppositions*.)

- What will be the problem of the day be around which the group will be brainstorming. Examples:

"What can we do with this upcoming bid to stay strong in the missile business?"

"What new markets should we move into or generate that leverage our strengths?"

"What kind of organization should we become (given a set scenario)?"

"Oops, something (particular) happened, what should our response be?"

Once the problem is understood, you announce that we'll brainstorm on one of the *world view* (religious) issues. Go around the room and ask each person to identify their default position on that issue. You'll probably start with the simplest issue, *centralized* versus *decentralized* control. The process of declaring players' underlying beliefs is a little tricky; since many folks haven't considered their positions before, they may claim to be naturally of one bent while it is historically clear that they are in the other camp. That's okay. Don't get bogged down in this. Take each player at their word. Now, ask each person to take the opposite position for the game,

Divide the group up as evenly as possible into teams. Ideally, the facilitator knows the personalities involved, and is able to level the teams in terms of argumentative ability. The effort may be wasted if a balanced dialog cannot be maintained and unless each person (as well as each team) gets their say.

The game proceeds with few rules, as an informal debate. Each side projects the stated problem according to the basic assumptions they have temporarily adopted. The nature of advocating each position should include arguing against the position of the other side. What creates the richest possibilities are three things:

- That bright people are using perspectives which are contrary to those which they otherwise use (outside of the brainstorming exercises)
- That they actively advocate those positions (and present new approaches to products, markets, business strategies...)
- And that the basic issues (on which the positions are based) are defined in a way that mirrors fundamental controversies both with their natural divisions, and in ways that spawn or leverage robust memes.

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In conducting the exercise, normal group management skills apply; keep the focus, watch for dominating speeches, repetitive exchanges, and dwelling too long on a topic. You should arrange to have an out-of-character signal, so that a person can stop to ask questions if needed, but otherwise save comments and complaints for the time between rounds. Unless the signal is invoked, all players are presumed to be in character.

Each round should only last *30 minutes* or so. During this time, it's often the case that players are dying to take the other side's position. So it's a good idea to give the option of swapping sides for the subsequent section. Don't worry about people stretching their assumptions if they switch back to their natural beliefs. By this time things will usually have transcended preconceived constraints.

Select another set of basic issues, choose sides again, and have another round, still working on the same problem. It is up to the facilitator to select a basic controversy that is apt for the problem and also takes advantage of some of the issues raised in prior rounds. Players tend to carry over gems from one round to the other, and it's good to provide a different medium for forming the thought.

Only spend 2 or three rounds per problem statement. You'll quickly exhaust the pool of spontaneous insights. Move on to another problem statement. If you have an important problem that you really need addressed, make it the second problem, having the first be a warm-up. But don't make that first one trivial.

The whole session should occupy no more than a morning or an afternoon. The facilitator should not be any player's supervisor, and the session should not be tape recorded. All these are impediments.

In many cases, the payoff comes in a second session in a few days or a week with the same players (no more than two substitutes). This time, everyone understands the idea of playing a role, and you'll have some results to report from the first round. If the analysis between sessions is competent, and the group is typical, they'll be surprised at the gems that can be found; they zip by so fast when the discussion is underway, they're not noticed.

This general method was created, refined, and validated by the AVE Focus Group and has been used elsewhere with positive results. In all cases, the topics were not narrowly constrained to engineering an AVE.

6.4.1 Future Work: the Dooley Graph Link

[Still to be done is mapping this method at a finer level of granularity so that the role playing can be simulated by agents.]

We envision adding another dimension of the structured controversy method: fleshing out the structure of the basic controversies which have been defined (Soft modeling), and focusing in on engineering of agile systems. In particular, we believe that certain configurations in an organization are *inherently* agile (given certain contexts), and that those configurations create recognizable patterns in the resulting Dooley Graphs. This insight extends the brainstorming method from a

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role-playing game to utility by an analyst or analytical team using a modeling workbench.

This is work to be done by others, for instance as a followon to the agility research of the Work and Technology Institute.

Part 2, Agility Issues

Part 2 is targeted toward the reader who is interested in indepth discussion of issues which surrounded the project.

7 Abstract

In this part are collected a number of results which were incidentally reached. There are a few examples given: agility as competitive weapon, and extremely dynamic market forces. The benefits to the U. S. economy and the defense base are reviewed.

Projects which lead up to the metrics project are summarized, as well as technical efforts which contributed to success of the effort. An exhaustive examination of definitions is given: The virtual enterprise, the agile virtual enterprise, and many issues related to metric.

We compare agility to many other efforts which benefit an enterprise, and other sponsored agility research.

A short summary of the approach is recounted and known limits are reviewed.

8 Agility is Different

[A case is made that agility is both important and fundamentally different than other management concerns. Examples are given where agility (or lack of it) is a factor. There's an example of an instance where lean is not agile. We outline steps for agility thinking.]

A major challenge in life is discriminating what is changing from what is not. What's new is that not only is the rate of change increasing (changerate) but the *things that change* are changing. It's no longer sufficient to be fast, not enough to be able to respond nimbly when change is recognized. Firms need to *engineer* the ability to respond to specific types of change.

When Wang Laboratories invented the word processor, an innovation that quickly created a billion-dollar company, shock waves hit the world's largest typewriter producer, IBM. IBM had dominated the typewriter market with the most preferred products, but they were initially unable to respond to Wang's innovation. Wang successfully redefined and dominated this market precisely because they took advantage of change.

Yet, when Wang's market started eroding with the appearance of word processing software on personal computers, they were themselves unable to change. At the time, a Wang official confidently declared,

> "We're a billion-dollar company and billion-dollar companies don't disappear overnight."

But when IBM faced and responded to the new realities by creating the word-processing capable personal computer, Wang was unable to change, and they were soon bankrupt.

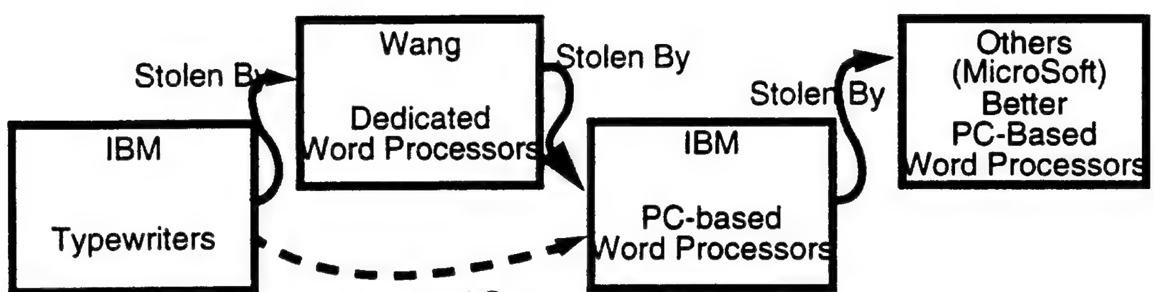

Figure 8-1:A Multiply Stolen Market

At one time, vacuum tube giants GE, RCA, Raytheon, and Sylvania absolutely controlled the electronics industry. But they do not today; others seized many of the new opportunities. Are the current leaders equally temporary? There are so many examples of companies not being able to change--to keep up--that one has only to go back a few decades to see a 50% turnover in the Fortune 100.

What did the losers do wrong? These firms, most of them, were paragons of good management; they delighted their customers with excellent sales personnel; they had, relatively speaking, *flat*, knowledge-driven organizations and empowered, educated workforces. But they could not *anticipate* change. Who could? Their actual problem was that they couldn't respond to the unanticipated change even when knew that the earth was moving under their feet. What they lacked was

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agility, which we define simply as the ability to respond to unexpected change. The research on which we report provides help toward a better understanding of agility as well as specific steps on how to engineer the correct amount and type of agility into an enterprise.

One thing is clear: agility is largely independent of other best management approaches that a business can practice. Your ability to make things *better*, *faster*, and *cheaper* today says nothing (or very little) about your ability to change (in a fast and cheap way) to make *something else* better, faster, and cheaper (or to respond in other respects to unanticipated changes).

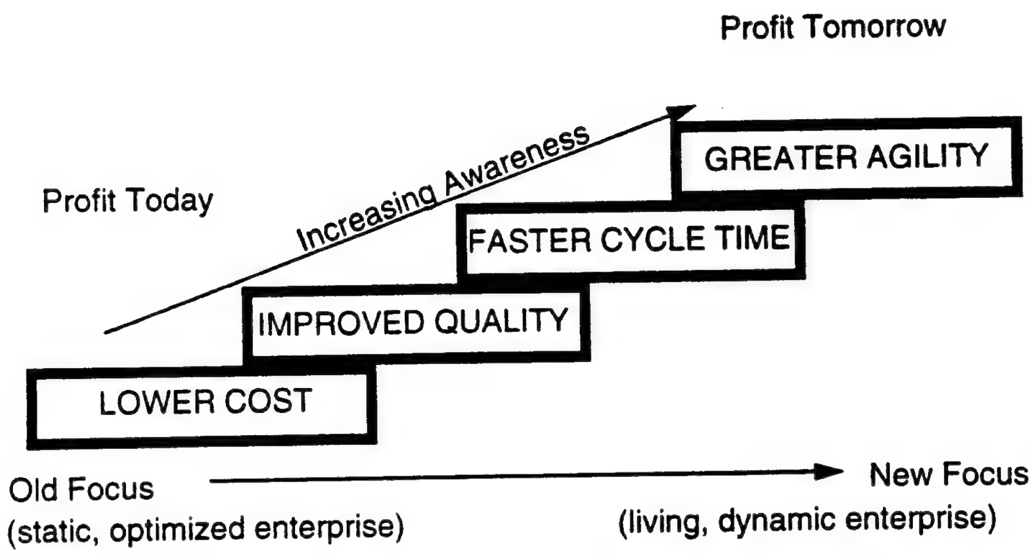


Figure 8-2:On Beyond Better, Faster and Cheaper

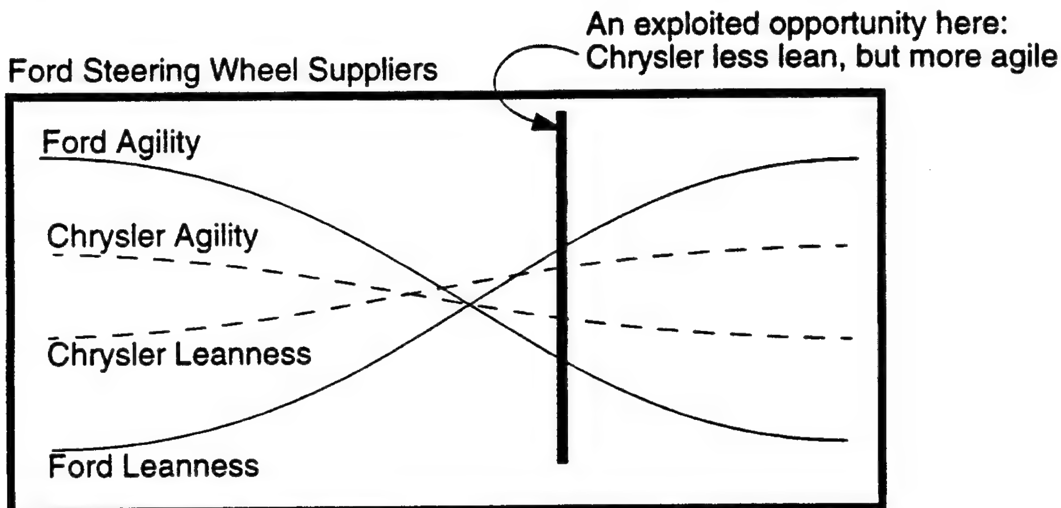
If you have a flat organization, according to best-in-class standards, will you be more agile? Maybe not. In fact, what put Wang out of business was IBM roaring back by entering (some would say creating) the PC business. IBM was able to respond successfully because of the previously underutilized skills of their *thick*, many-layered technical management pool. They continued to be remarkably successful in responding to change in the PC business as long as they could handle it in the same fashion as their typewriter business (as personal letter-writers and adding machines). When PCs started looking more like other computers, and competed with their *other* business (mainframe computers which, inside IBM, used another paradigm), they had troubles. But that's another story.

If you have a lean organization, as conventionally understood, will you automatically have agility? Consider the following example. Toyota, and other Japanese auto manufacturers, gained a foothold in the U. S. originally because they happened to be making small, efficient cars at a time when the oil price shocks made those cars attractive to U. S. buyers. Originally, the attraction to the consumer was simply the size of the car and a low price resulting from an artificially strong dollar. Quality wasn't part of the equation at first. U. S. automakers were stuck, having

invested in plants and processes for larger, gas-guzzling cars that it was hard to adapt to the new kind of product.

Later, both quality and *lean* production techniques quickly became competitive issues. Ford and GM rushed to become lean. The first targets were reductions in their supplier base, with the remaining pool being more *qualified*. Most initial success was in drivetrain suppliers. Both GM and Ford went from a very large pool of suppliers to a highly integrated, much, much smaller set. Savings were immediate.

Meanwhile, Chrysler was not becoming lean as fast as Ford and GM, and it was not doing well in the market either. Consumers just weren't buying many of their cars. Chrysler decided that a good selling point would be to offer driver's seat airbags, and they did so. Ads, featuring their CEO, touted this advantage.



In introducing airbags, Chrysler exploited the fact that Ford's rush to reducing suppliers rendered the supply chain less adaptable.

Figure 8-3:Agility as a Competitive Weapon Against Lean

We've heard two versions of this story, one of which makes Chrysler appear wiser than the other. What happened was that Chrysler was far behind on becoming lean, insofar as reducing suppliers. So they had a large pool of steering wheel suppliers. Since installing airbags in steering wheels stretched existing processes considerably, it was helpful to have this large, competitive pool. Ford and GM took years to adjust, hampered by their lean supply chains, which were efficiently targeted on *old-style* steering wheels. Meanwhile, Chrysler attracted a substantial number of crossover buyers. One version of the story has Chrysler targeting this weakness accidentally. Another, less likely, version credits Chrysler with *intentionally* hitting their competition where they were weak, meaning un-agily-lean.

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We assert that agility is something separate and apart from being better, faster, and cheaper, merely being profitable *today*. Rather, it is the ability to be profitable *tomorrow*, presumably by being better, faster, and cheaper in different ways. Agility is a concept that investment firms implicitly understand and use. Everyone can

see how profitable you are today; that's not the most important question. An investor is more concerned with *how likely you are to be profitable tomorrow.*

In a sense, some agility is free. You can get a limited amount of agility by employing good management practices that you have may adopt independently of agility concerns. For instance, good customer monitoring has to be helpful all-around. If you invest in better, more robust insight into customer needs in order to be profitable, that's also likely to help you be agile.

But most agility will cost money. You'll invest in agility as a hedge, much as you already do with insurance coverage. Some would say the least useful kind of agility would be an excessive capability for change and especially for change that is in the wrong areas--in other words, agility that you never use, that you spent your stockholder's money on and didn't need. But even more crucial in many cases is the agility that you do need but just don't have, which hurts your position. Just like insurance.

This report describes work on metrics for agility. The metrics are intended to provide a first step toward a management science of agility, and to be immediately useful to managers wishing to make informed decisions about agility. One application is in a three-step agility assessment:

Step 1 in the assessment would evaluate the threat; identifying the areas in which, and the extent to which, agility would be required. This step gives your best guess on how unstable the sand is under your feet and in which direction it is more likely to slide. Our new metrics will not help with this particular evaluation, other than to generally illuminate the dimensions of the problem. We consider that conventional actuarial analyses can cover this problem, fitting right in with other strategic evaluations of change within the environment. But we do suggest a promising structured controversy brainstorming technique.

Step 2 in the assessment would be to evaluate your ability to address the threat. Here, we will be able to help you predict the time and cost of change, given specific configurations within your enterprise.

Step 3 would direct you to specific tools and techniques, ideally through case studies, to address your specific weaknesses. Several groups are working this problem, the most notable the Agility Forum at Lehigh University, and the three Agile Manufacturing Research Centers. As with step one, our metrics only generally inform this step, except through the rules of thumb noted below.

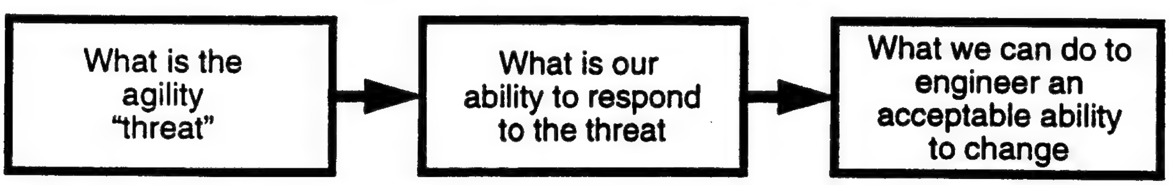

Figure 8-4:Three Steps

The targeted initial use of the metrics is as a tactical tool: you *already have* a corporate or enterprise strategy, which has as a component where and how much

you want agility. You are faced with a given number of alternatives, for example, competing members within your supply chain. Naturally, you have ways of evaluating the time, cost, and quality of these suppliers in the static situation. We'll help you determine the time and cost of change in the manner and extent that your strategy requires. So, the actual, real overall cost of doing business with them as conditions change can be evaluated (by combining the results of our metrics with your measures of better-faster-cheaper).

We'll give some indications about the use of the metrics for the more technically challenging situation of strategic planning. Here, you would need to incorporate the metrics with your own (or your consultant's) strategic analysis tools; you would need the ability to perform quick evaluations as well as high confidence simulations; and you'd need the ability to evaluate many options with many alternatives, taking into account numerous factors in your organization and those of your partners, competitors, and customers.

Perhaps the best use of this type of strategic agility is as an active competitive weapon, not merely a response, as in one interpretation of the Chrysler experience. An example of agility as a weapon is available in the famous *Burger King assault*, described below.

Finally, we expect that one result of adopting this approach to metrics will be the appearance of certain rules-of-thumb for particular situations in agility which can be applied even without the specific analysis by metrics.

In addition to the targeted use of metrics by strategic managers and middle-level decisionmakers, we also expect these metrics will be used by the investment community to evaluate companies' future prospects.

8.1 Burger Wars

[An example where agility is used as a competitive weapon.]

For the Best Agile Practice study we interviewed a number of companies, some of whose cases were not used in that report. This case was too old and too complicated to fit the Forum's template, but is quite interesting nonetheless. These insights come from a senior VP/strategist at a fast food parent company who spoke from experience.

Most of us will remember the early days of the burger wars. MacDonald's was the Toyota of the restaurant business; it emphasized *lean* (no pun here) processes based on burgers, shakes, and fries, and they took the nation by storm, offering the advantages of low cost and convenience.

My informant described wonderful examples, well known in the literature, he said, of detailed studies of such concerns as the optimum combined grill/spatula size, and a shake process which knocked 1/2 second off preparation time, and so on. The entire kitchen was based on the most efficient processes geared to an extremely limited menu. A tremendous investment went into understanding those processes and designing the best equipment and processes.

Part 2, Agility Issues

MacDonald's ended up with a huge physical investment in equipment which was optimized for a small, standardized menu set. Enter Burger King. They put themselves on the map by pursuing a brilliant strategy: they figured that people would tire of burgers alone, if they were reminded of the monotony. So they began via advertising by sowing dissatisfaction with the standardized condiments on premade burgers.

Burger King designed a set of assembly line equipment and processes which did cost more, but were also more agile in a way that their competition couldn't match. You might remember the system, a two-tiered moving grill conveyor, the top for toasting the buns, the bottom for the meat. Burgers were made one at a time, the process beginning with the customer's order.

The tactic was to emphasize that the customer could have it *their way*, with a tailored set of dressings. And they advertised the dickens out of it, educating the customer to expect more, and this severely hurt MacDonald's. During this period Burger King's growth far exceeded MacDonald's. This provides an example of agility employed as a tactic specifically targeted to the weaknesses of a lean competitor. But the initial agility was focused on the physical infrastructure, exactly as in flexible manufacturing.

The longer term strategy was even more interesting. Burger King figured that they could use the equipment and kitchen layout for a larger, more dynamic menu. It was specifically designed for agility in this way. Burger King impinged on MacDonald's business by offering a steady stream of *specialized* sandwiches, emphasizing their variety (including different shapes, a feature very hard for MacDonald's to imitate). They knew that by changing consumer expectations in this way they would force MacDonald's to completely reinvent their processes and to replace all of their equipment.

And it worked. MacDonald's had to toss out all of their special equipment and replace it with a more flexible physical plant. The resulting cash demands on MacDonald's allowed Burger King to grow unchecked to be a nearly-equal competitor, since they could use *their* money for marketing and growth. Incidentally, MacDonald's learned a lot about using the physical plant as a competitive weapon. In the process of remodeling, they invested in playgrounds in the restaurant, creating a niche and providing an attraction that Burger King could not boast.

So far, we have an example with agile adjustments in physical and legal/explicit (in this case, the process plans) infrastructures. As it turns out, the processes and equipment used today have been revolutionized by changes in the information infrastructure. Burger King, MacDonald's, and others are now pretty much the same insofar as processes and equipment are concerned. Meanwhile, Rally's and others have made a thriving business by entering the niche that MacDonald's left: a very limited menu produced by an optimized, cheap kitchen.

The dynamics are exactly as found in the Chrysler steering wheel example.

The burger war historian told us that today, significant competitive differences among the big players focus instead on a variety of human, social and intangible elements. Some of these shed light on our soft agility studies and will be explored

later. For now, we can at least notice these four categories of infrastructure--physical, legal, social, and informational--all of which provide opportunities for agility. We characterize these categories and address the opportunities in Part 1.

8.2 Competitive Games

[An example sector where market share is highly dynamic.]

Examples are distributed through the report. But of all sectors, consumer electronics is the most dynamic; and within that sector, the game console industry is pretty interesting.

The story begins with Nintendo introducing their NES to great success to capture a market orphaned after the Mattel/Atari collapse. Their approach was much like Microsoft's in the personal computer business: capitalize on the large user base to quickly build a massive cadre of good and not-so-good developers to deluge the market, creating a proprietary product stream which completely dominated the market.

Along comes Sega, with a superior platform, the 16-bit Genesis. It only had a few games, but each was the best in class. In a new business model, Sega worked only with a select group of developers. Newer games were few, but excellent. It was a formula that worked. Nintendo, completely stymied, was sunk. The release of their Super NES was much too late. Nintendo had lost, because Sega changed the rules.

Nintendo held on to niches (Japanese, Gameboy), while Sega moved to consolidate power with its Saturn. But the rules were to change again. Sony is a master of advertising, and they recognized a malleable market. In a blizzard of advertising, they swept in with their PlayStation and completely beat the pants off of everyone. The older players had wearied themselves in a feature war, and Sony had trumped them with promoting image.

But wait! Recently Nintendo moved to redefine the industry back to excellence of product. They introduced their Nintendo64 (with Mario64) and sold out in stores everywhere in hours. The consultants who worked on this project revealed the hidden strategy. In an industry where huge leadership swings took place (Mattel to Nintendo to Sega to Sony and back to Nintendo) the winners are the ones who can completely redefine themselves both in response to threats and to strategically redefine the rules to be most uncomfortable for the competition.

The trick was to become *agile*, to use agility as a weapon. You know who they took as their example? McDonnell Douglas, the group that designed the space station and redesigned and redesigned and redesigned it in response to a fickle customer (the micromanaging Congress) until learning how to change the rules so as to manipulate the situation.

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Part 2, Agility Issues

9 Government Sponsorship

[This section outlines the sponsors of the project and provides a rationale for them to lead agility research.]

9.1 What is the Domestic Advantage?

[Results of studies on agility benefits to the economy.]

Government support of agility can benefit the U. S. Economy.

Since a primary goal of AVEs is increased profitability and productivity in business enterprises, the U. S. economy will benefit in the aggregate. How much productivity will result is impossible to predict; some widely circulated numbers are not supportable. With key infrastructure suppliers, we conducted some in-depth studies to shed light on the benefits of the VE, producing new knowledge in key areas, some of which is reported below.

9.1.1 U. S. Enterprises Benefit Relative to International Competitors

[Agility leverages U. S. strengths in innovative small businesses and case law.]

We studied the costs of integrating and managing processes in the U. S. compared to the international competition. The results were startling. The study focused on high-value manufactured components, because this is where the major competition exists. (A high proportion of foreign low-value manufacturing and assembly directly benefits U. S. business anyway.)

In every case examined (automobiles, commercial aircraft, consumer electronics, small appliances, semiconductors) the major determining factor in the competition's relative success was not low labor cost, access to cheap capital, or the benefit of government-sponsored research. Rather, it was the low cost (relative to the U. S.) of integrating their enterprises. (A parallel study was performed, with similar results on the Soviet, now multinational, military aircraft enterprise.)

The reasons for this are related to how we and our competitors traditionally do business. When Sony designs a product, they do so knowing who is going to build its components, so they can predict or dictate what processes are going to be used. The typical Japanese enterprise is a very stable, vertically integrated enterprise. The typical European enterprise is similarly, though less, integrated and stable, but without the shared ownership which characterizes the Japanese.

A typical U. S. enterprise is dynamic; the rules of composition are dominated by the forces of competition. The major benefit of this system comes from the innovativeness of small, agile businesses. In this area, the U. S. is unparalleled. However, the cost of quickly integrating processes of a small business (or component of a large corporation) into the *supplier chain* is excessively expensive in terms of effort, time, and cost. This amounts to a critical disadvantage for U. S. enterprises.

In a growing number of U. S. industries, a quantity of small business innovators are being driven out of the supply chain by the increasingly high cost of doing business. Pressure comes both from within the small businesses, who would rather put resources on their core competencies, and from large *primes* who prefer to reduce

the number firms *under* them, to reduce the cost of integration overhead. An otherwise classified study has reported a disastrous decline in the number of small, and presumably innovative, businesses involved in the current generation of aerospace weapon systems.

This phenomenon was directly linked to higher costs.

The studies indicated that if the cost of assembling an integrated U. S. enterprise were lowered, then the relatively stronger engines of innovation and competition would put every high-value U. S. manufacturing enterprise at a structural advantage. The international competition would lack the agility to keep up, as their staid, long-lived structures would be slow to evolve. Their reliance on vertical integration and stability is intrinsically unagile.

Additionally, it was found that improved capabilities in non-manufacturing information infrastructure in many cases resulted from improvements originally funded by the manufacturing sector. When VE suppliers were polled under nondisclosure protection, it was found that 62% of all improvements underway were driven by market forces originating with manufacturing customers. (All numbers in this section are from 1993.) Thus, other business enterprises (financial and retail services, or petrochemical/pharmaceutical industries) and nonbusiness enterprises (government and nonprofit activities) will benefit directly from attention to the industrial VE.

A surprising competitive advantage was discovered: the use of common (or case) law in the U. S. Most of our international competitors (the European Community, Japan, other Pacific Rim countries, and in the future, China) use law based on code. The movie/whaling example shows one direct advantage from the U. S. system. It would be desirable if the infrastructure, and specifically the metrics, were engineered to leverage this advantage. So we can consider this both as a present structural advantage and as a potentially greater advantage.

9.1.2 U. S. Benefits as Suppliers of VE Infrastructure Products

[The U. S. is likely to provide the majority of the agile-sensitive information infrastructure of the world.]

The idea of suppliers of VE infrastructure is a new one, so we had to conduct some market surveys to understand the dynamics and characteristics of the VE marketplace. The studies used the ICEIMT [GORA92a] definition. VE infrastructure technology suppliers were found to be different from VE service/application suppliers. The latter are characterized by large users (Boeing, GE, GM, the manufacturing side of IBM for examples), who supply services to themselves, and system integrators who supply services to others. The service suppliers can add value only within the range of the capability envelope provided by the technology suppliers. Therefore, the chief pressure-points for VE capabilities are the technology suppliers.

This group of companies is surprisingly small in number, consisting of IBM, Digital, and a loose federation of companies (including those mentioned) which add value to UNIX (Hewlett-Packard, Sun and then NCR). (Microsoft, Apple, and Unisys

were not critical players in the manufacturing enterprise as of 1992, the time of the study. Since then, Netscape and NeXT have also emerged as players.) That these companies are in the process of redefining their infrastructure products is good news for the VE program. Also important is the fact that all of the major suppliers are U. S.-based firms.

In fact, if the larger companies are decomposed by national geography and VE-related infrastructure products are assigned to the decomposed elements, some interesting insights are gained. If one counts a non-U. S. based component of, say, IBM as a *foreign* company, and the U. S. based component of a non-U. S. based company also as a foreign company, 73% of all VE technology still comes from a U. S.-owned component based in the U. S.

The U. S., therefore, currently has most of the jobs, the technology, and the market of a potential VE infrastructure economy. As the VE market grows, the U. S. will experience growth in this market sector, as a first order economic benefit. It is notable that these VE technologies fit the traditional definition of strategic technologies: they are the beginning of the food chain for most of the world's industrial economy. It is possible that, as routine integration becomes simpler, the systems integration *middleman* business will shrink. As a result, U. S.-dominated VE technology suppliers will become more strategically important to world business.

9.1.3 U. S. Benefits as Suppliers of VE Infrastructure Processes

[The U. S. is likely to supply a high percentage of innovative process technology into a world of agile enterprises.]

By most measures, the U. S. is the most active developer of process-related intellectual property in the world. In another study, we sought to understand the potential for a new trade based on the licensing of process-based intellectual property from one firm to another. It is considered unlikely that an enterprise would wish to transfer processes which it uses to competitive advantage to a competitor. So attention was given to processes which could be traded across business sectors.

This was a difficult analysis; while businesses know how much they spend on hardware, and try to know how much they spend on software, there is presently less incentive for knowing how much is invested in process development. Proprietary information supplemented new floor surveys (under our initiative) in statistically representative manufacturing companies. The category of process-related investment was called Enterprise Characterization [GORA92b]. In general, this category consisted of all explicitly captured process information which is recognized in some way by the information infrastructure.

A staggering $160B per year worldwide is spend on enterprise characterization. Within specific sectors such as semiconductor manufacturing 90% (plus or minus 5%) of a huge amount of money was spent on characterizations which are common (i.e., shared and potentially-transportable). 70% of the money was spent on characterizations found to be common across the electronics and the automotive manufacturing sectors. Transportability of processes in the case of service sectors was

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not easily determined. Of these expenses, 70 to 90% was deemed actually feasible for commerce (i.e., for selling processes), depending on the industry. The enterprise characterization components had a surprisingly long life, a half-life of 7.5 years. This indicated that a several hundred billion dollar economy in process technology is theoretically possible, though of course probably in practice somewhat further limited by other legal and market forces.

U. S. firms would benefit by being able to avoid reinventing processes by acquiring those not in their core competency, including processes developed overseas. Some U. S. firms would benefit from selling processes to non-U. S. companies in other sectors, allowing increased investment in new processes.

(A much more detailed Suppliers' Working Group report on these issues is available for internal government use from the Air Force Wright Laboratories Manufacturing Technology Directorate. This combined proprietary information from many sources to obtain results and is not available to the public.)

9.1.4 User Firms Can Leverage the AVE

[Agile enterprises are more likely to do well in other desirable traits, such as quality and productivity.]

Often, industrial users consider the primary advantage from VE to be in its empowering of some technical strategy which they deem important to their competitive posture. These strategies are diverse, and none of them apply to all sectors. But in each case, the VE can provide an underlying infrastructure which empowers *Agile/*Flexible*/Rapid-Response/*Lean Manufacturing, *Total Quality Management,* Concurrent Engineering, Soft/Virtual Prototyping*) or* Electronic Commerce. Occasionally, the user will eschew these concepts to focus on a single metric, such as improved quality, reduced costs, reduced cycle time, enhanced markets or flattening of the organization.

For many of these cases, limited tools already exist. But the market for any one of these applications is too small to effect a major change in the basic infrastructure. Yet if one envisions the components of the AVE as including elements within an enterprise, then the technical requirements of the AVE cover many of the harder issues of these applications of enterprise integration. The VE provides an overarching concept which unifies some technical issues among the components and opens the market sufficiently to warrant addressing the tough problems.

Champions of all the above-mentioned approaches have presented business cases. Some of these are more developed than others. But it is clear that if the AVE contributes to the success of any of them, major benefits to industry will accrue.

9.1.5 New Entrants into the Market will be Possible

[It will be easier for innovative startups to thrive, another U. S. strength.]

Currently, the major VE technology suppliers are all hardware suppliers. This is a legacy of how the market developed: first as operating environments, then as layered *middle-ware* components in (a) larger system architecture(s). Often the oper-

ating environment is the competitive discriminator among suppliers, and the barriers to entry are substantial.

As proposed, the AVE will *open* the market so innovative firms could enter all or part of the market. This could help revitalize the software industry by itself, and most of the likely entrants are U. S. firms.

9.2 What is the Defense Advantage?

[Results of studies concerning benefit to U. S. defense. Defense industries cannot be agile unless commercial tools exist. If so, civil suppliers can be shifted in and out in both peace giving lower costs and mobilized for emergencies, providing a lower cost for readiness.]

The case here is straightforward and follows the long-lived ManTech tradition. The Defense Industrial Base is less than 5% of the manufacturing domestic product. It is simply too small to support any particular type of VE infrastructure, especially one that promotes a radical idea like agility. The only way to get improved VE infrastructure into the defense base is to see it widely accepted and supported in the domestic commercial base.

Elsewhere, we will make the case that there are few barriers to cross in tailoring the AVE tools, specifically the metrics, in cutting across defense and commercial users. Fortunately, the defense users of interest, teams which design and manufacture complex weapons systems, represent essentially the same type of constituency for agility in the commercial base. In the latter case, the users will be teams making high-value added consumer products.

A second order benefit concerns the two meanings of dual-use. The conventional use of the term applies to a team's ability to adapt existing processes from commercial use to military in times of crisis. But there is a much more promising vision which agility empowers. If there is a high degree of agility in practice, then defense AVEs should be able to readily form in non-crisis situations, drawing from the civil supplier/subcontractor base.

This larger pool would provide for more competition: lower prices and greater innovation.

In fact, the need for this latter vision is already upon us. The U. S. defense strategy depends on an ever-increasing ability to field more and more sophisticated weapons while at the same time reducing support for a dedicated infrastructure to do so. Only a commercial base capable of AVEs can support this need.

10 The Legacy of this Approach

[Prior work gave the project a running start. It is described here.]

This project was small and brief. It was supplemented by industry participation which leveraged the government investment manifold. But it also leveraged preceding defense manufacturing programs as well as parallel research in non-defense manufacturing areas. This section provides just a brief overview so that the reader can place the presumptions of the project in a meaningful context.

10.1 Preceding Work

[How a specific thread lead to the project. Includes a $40M private study.]

For decades, the intelligence community has dealt with the problem of many independent sources providing intelligence to many independent analysts. Yet all these parties are expected to virtually aggregate to supply coherent perspectives on *big-picture* issues. Many of the sources collect, manage and provide their information in different forms (interviews, photographs, parametric data), using different assumptions. Likewise, the analysts use different tools and assumptions.

The situation is similar to the design/manufacturing AVE in many ways. Different skills, world views, models, organizations, cultures are expected to automatically integrate around a specific customer need, a query. And this generally happens well after basic individual collection/analyst infrastructure (the equivalent of the *supplier base*) is mature.

In recognition that a specific research program in the intelligence community had the best handle on this model/agent federation problem, there was an attempt to transfer technology to the Space Station program early in its life.

There was a recognition that the Space Station was a highly complex, multipurpose device, of which one would be made that had to be essentially perfect for 30 years. It was to be created by a highly decentralized mob with diverse, dynamic technical and cultural goals. One billion dollars was set aside for the Space Station Information System, an AVE-enabling federating infrastructure.

After substantial technology transfer and expenditure, the program was eliminated (the political particulars aren't central to this report), and the researchers migrated to defense applications. The Advanced Technology Bomber (B-2) had a true disaster story resulting from its attempt to avoid federation by frail central information management. The effort moved to support a program called the Automation of Technical Information, later known as CALS. CALS, phase II was also known as the DARPA CAPS (Computer Aided Procurement/Production Support/System).

Through other political foibles, CALS became a standards effort, and CAPS evolved into DICE, the DARPA Initiative in Concurrent Engineering, and also into the SEMATECH effort. Both of these anchored the new DARPA Defense Manufacturing Office.

SEMATECH is a two billion dollar research program, jointly funded by the Defense Department and semiconductor manufacturers. The rationale was to preserve a domestic supply of modern integrated circuits for defense use in the face

of aggressive and possibly offensive Japanese practices. There were several constituencies behind SEMATECH, and these competed for attention and resources.

The constituency that got the program funded (Congress, Defense and the major firms) looked at the problem as not one of manufacturing chips, but manufacturing *chip-making factories*. Making these factories is a big problem:

- they cost between $1 and 2 billion apiece
- they involve thousands of suppliers of equipment, processes and material
- the product (the factory, or *fab*) is an extremely high-tech item
- many components from suppliers differ in key ways from similar components they've supplied to other fabs; most fabs, even within the same company are unique in key ways; the rate of change of components and fab architectures is increasing
- the profitable lifecycle is short, only a few years, then essentially everything is obsolete
- the key to success is to get all this integrated quickly so that the yield goes up and you can hit a slender, product technology-driven opportunity window

This is the AVE problem. A special subset of SEMATECH spun off independently as the Suppliers' Working Group (SWG). This was a special project facilitated by DARPA/ManTech. The *suppliers* were potential AVE infrastructure suppliers.

Hundreds of millions were spent researching some of the thornier problems in federation in the AVE context. This was extremely influential work, essentially none of which is in the public domain, save the SWG-sponsored ICEIMT [GORA92f].

This work, and industry attention, was brought into the metrics project, allowing for the substantial leverage over the project's small, direct funding.

10.2 Parallel Trends in Theory

[Several scientific trends provided low cost leverage by having ready answers when needed.]

Several parallel trends were folded into the effort. These also had the effect of expanding the impact and leveraging the funding of the project.

10.2.1 Linguistic/Syntactic/Situation Theories

[Recent trends in Situation Theory were helpful.]

The metrics depend on understanding dynamic coupling of processes through the structure of how they communicate. Real vibrant science of communication is full of differing perspectives, esoterica, and emerging results.

The dominant thread has always emphasized semantics, the *meaning* of communication. But there have always been alternative, complementary branches of linguistics, language and mathematics which focus on the structure, syntax and context of communication.

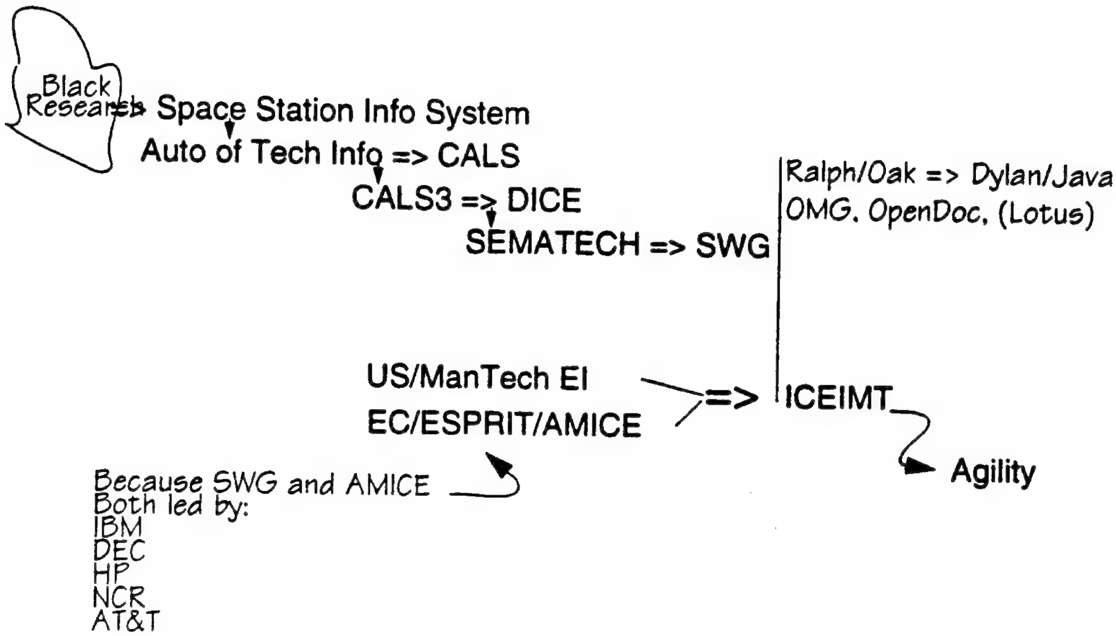

Figure 10-1:Contributing Programs

In particular there has been a branch of information science which is interested in the complexity of computer programs. Questions of interest are the intrinsic computing *cost* and *adaptability* of computing languages and algorithms.

Another pertinent area is that of *Speech Acts*. This line of thought originated in studies of cognition and communication, and is a central part of much thinking in artificial intelligence and knowledge representation. It is particularly useful to those working in Multi Agent Systems.

The final of these three trends is Situation Theory. Originally it was developed as an alternative to Chomsky grammars which places primary emphasis on the structure of an utterance. Situation Theory emphasizes more indirect and contextual communication. The Stanford Center for the Study of Language and Information was the focus of this work.

The union of these three, through our BAST (Business Applications of Situation Theory) workshops accomplished within the project, provides us with a basis for:

- decomposing processes *and their contexts* into speech acts
- understanding and reasoning about the processes and contexts
- measuring their complexity and adaptability

10.2.2 Category Versus Set Theories

[Work in the structure of transforming actions provided some of the foundation.]

Early in the history of logic, the mathematical foundation of logic became identified with the mathematics of sets via *Set Theory*. Essentially all of the implemented engineering principles in programming follow this tradition.

Yet, mathematicians have developed a parallel tradition based on notions of types and functions. This *Category Theory* can also be used as the basis for logic and language, equivalent to set theory. But it has advantages in identifying the transformative process at work.

Category Theory, while relatively unintuitive compared to set theory, works well with the linguistic ideas noted above, because the structure of the *process* is more clearly revealed. As a formal basis, Category Theory also better supports the implementation strategies noted below, for similar reasons.

10.2.3 Group/Graph Theories

[Group theories provide an expected boost in support tools for analysis in a second generation.]

Syntactic approaches with categoric underpinnings have been used in a research context for some time. A problem which has limited the approach is how complex the underlying mechanics become. This is a result that such approaches allow many types of abstractions to be easily created and supported. Without some sort of constraining methodology, the complexity of implementations becomes nasty and unsupportable for real world use.

We've spent a lot of time on this problem on the prior projects noted above, and feel that constraining the abstraction strategies by group-theoretic means is the answer. In computerese, this translates to constraining the typing strategies so that they have internal structure which you can count on to rigidly simplify constraints.

We expect to develop this idea in a tool strategy. The mechanics that an implementor can use have actually been well developed on the theoretical side of the physical sciences.

As an extra bonus, we've found that group theoretical abstraction (i. e. *symmetries*) helps visualization of complex situations by a user/modeler as well as supporting a decomposition within tools that componentizes them. Now, we begin to get closer to a strategy that can form the basis of mission critical, manageable information infrastructure.

10.2.4 Component Integration

[We leveraged emerging trends in infrastructure which will result in a new generation of tools regardless of agility.]

Modern tool strategies require that the tools be implemented as manageable components. As a practical matter, this means we need to componentize the abstraction strategy. But such a thing is only possible if the environment can support such a dynamic coupling between components which do the work, and components which represent fundamental properties about how you do the work.

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In particular, you need:

- *A reflective language*, a language that is self-aware of its own functional syntax and can modify the same. *LISP*, the original language of artificial intelligence was

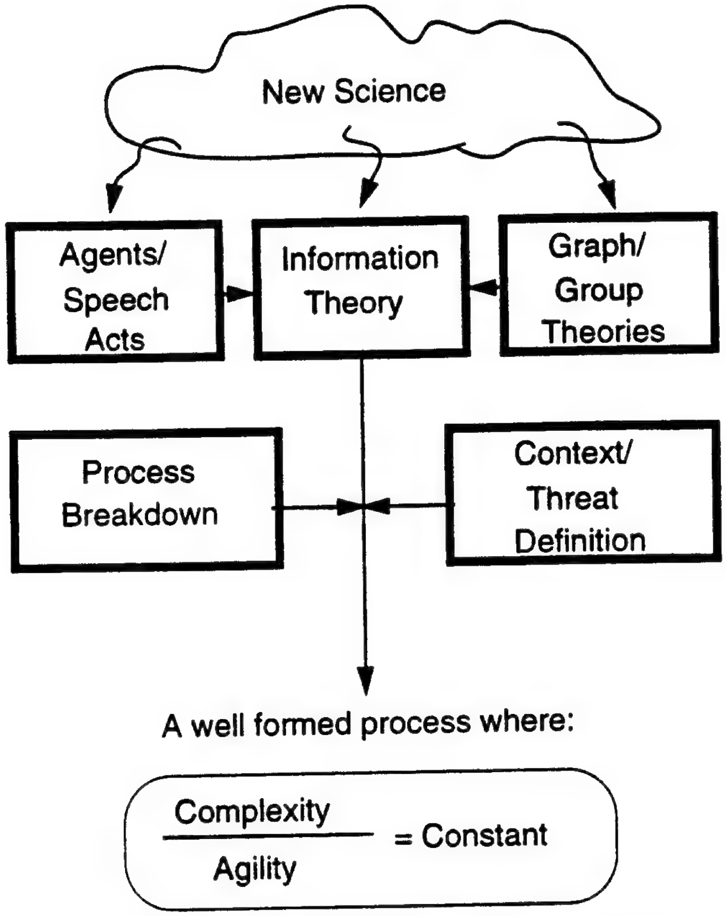

Figure 10-2:Several Contributing Components

designed with this in mind, and more modern implementations of this idea are *Smalltalk* and *Dylan*.

- *Dynamic objects* at the system level. This is a tricky one. The enterprise is defined by its infrastructure; its *information* infrastructure is both part of that infrastructure and representation of (the key elements of) it. If the idea is that the information infrastructure can *see* how the enterprise can change, it has to have reflection in its own definition, dynamic objects. The only production operating system that supports this is *NeXT. Taligent* would have also.
- *A model kernel*. At some point, you need to normalize the way you represent the environment and the way you represent information services in that environment. The System Object Model, *SOM*, provides this in addition to supporting more mundane implementation necessities.

10.3 What We've Done

[Some involvements we have to ensure visibility into these trends.]

The metrics project and its predecessors have supported progress in all these areas.

- We've supported the series of interdisciplinary meetings called Foundations of Information Science (FIS), which looks at fine-grained self-organizing agencies as a basis for adaptive, self-sustaining systems.
- We've created and supported the series of focused workshops, Business Applications of Situation Theory (BAST) to merge agent ideas, communicative acts, situation theory and category theory. This is leveraged through the pre-existing conference series: *Information Theoretic Approaches to Language, Logic and Computation* (ITALLC).
- We had a hand in organizing and supporting the International Society for the Interdisciplinary Study of Symmetry (ISIS-S) to bring group theory to general enterprise representation in a practical way.
- We play a role in the *International Society for Group Theoretic Cognitive Science*, which shares the few results in group theoretic abstraction.
- We established and managed the Suppliers' Working Group (SWG) which played roles in encouraging *SOM* and making it an open standard, *CORBA*; specifying the reflective language *Dylan*; and reflective enterprise operating system *Taligent*.

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Part 2, Agility Issues

11 Definitions

[Key definitions of the project.]

11.1 VE

[Definitions related to the virtual enterprise.]

11.1.1 Enterprise Versus Corporation

[Why virtual, why enterprise.]

Several groups use many of the terms that the project does, but sometimes mean quite different things. By *virtual*, we do not mean home officing of employees, for example. In the few sections that follow, we explain what we mean, and describe why.

Others say *Virtual Corporation* to convey what we mean by *Virtual Enterprise*. In neither case do we mean that it is not real, or does not manufacture real products. What is intended is that the grouping of people and resources has no collective identity either before or after addressing a specific opportunity. It is in a sense *promiscuous* in that its loyalties and the cost of disassociating are low.

Our concise definition of a VE is a: *Temporary aggregation of core competencies and associated resources collaborating together to address a specific situation, presumed to be a business opportunity.*

We have chosen to use *Enterprise* rather than *Corporation*, because the latter presumes that there is a shared vision of a corporate identity. *Enterprise* conveys the meaning that the shared focus is the work.

Corporation implies a conventional organization whose control is centralized, which is not what we mean. The VE is unified by its mission and distributed goals, not its control system.

11.1.2 Four Types of VEs

[We allow a wide variety of things to be called virtual enterprises, but impose a basic taxonomy on the major types.]

The Virtual Enterprise is defined as *an opportunistic aggregation of entities working toward a common goal*. The entities could be individual corporations, separate divisions in a corporation, or other entities, such as consumer groups or labor unions. Even with this definition, we cover a lot of ground. So we've broken things down into smaller categories.

Several different types of aggregation have been identified which range from more interesting to less interesting. The more interesting engage in novel business relationships which involve risk and reward. An attempt has been made to incorporate all of the different views, in a set of definitions that represent four types:

- *Type 1*: An aggregation formed in response to an opportunity. In its pure form, this is the prototypical (and most interesting) type where an entity identifies an

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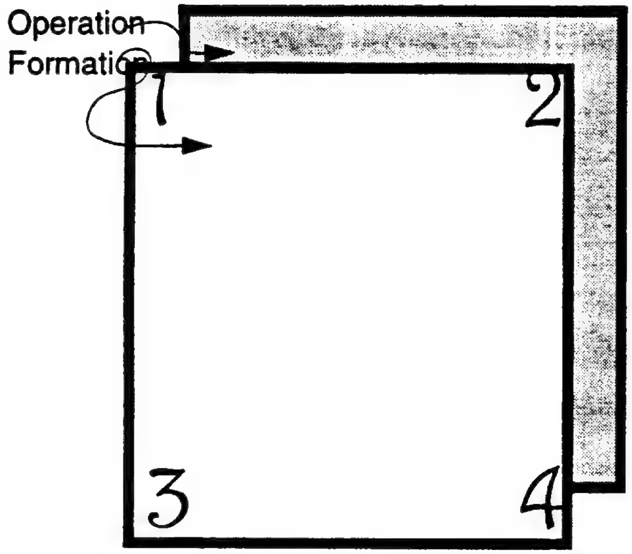

1. Opportunity-driven
2. Capability-driven
3. Supplier Chain (topdown)
4. Bidding Consortium

Types 3 and 4 aspire to types 1 and 2
No pure cases seem to exist
Best practices may be of different type
Types may differ between formation and operation

Figure 11-1:Four Types of Virtual Enterprises

opportunity (or recognizes a change) which takes advantage of a core competency. Then an entity (normally the one which recognizes the opportunity) acts as organizer to identify and creatively integrate partners with complementary, required core competencies.

- *Type 2*: A relatively permanent aggregation of core competencies that largely pre-exists, and which is seeking an opportunity. Generally, new members must be brought into the partnership in order to address the opportunity. Large corporations are often examples of this type when they have many perceived *core competencies*.
- *Type 3: A supplier chain* which, while using relatively conventional business relationships, exhibits agility in responding to market needs. Electronic Commerce also fits into this group when it employs traditional (albeit automated) business transactions.
- *Type 4*: A bidding consortium. Such a group relies on relatively conventional business relationships in its interactions. But it employs agile practices in response to market needs, and it acts as a Virtual Enterprise in representing collective capabilities to a customer.

One perspective holds that Type 2 is a special case of Type 1, differing only in the emphasis on the search for the opportunity and possibly the granularity and importance of the central core competencies. Another view, not in contradiction, suggests that each type can be cast in terms of an agile supplier chain or, alterna-

tively, electronic commerce. Considering AVE types in this light helps envision growth paths from a current, less virtual situation.

Each of the four types could result in Virtual Enterprises which are useful and profitable but not agile. The Agile Virtual Enterprise (AVE) is one that simply responds well (at low time and cost) to unexpected change. As a rough discriminator, however, a Virtual Enterprise is an AVE if it is formed with the intent of dissolving or quickly and cheaply reconfiguring in direct response to a change in the opportunity.

Of the four types, the latter two are less agile and virtual. The discriminator is the ability of each component to change the way it does business within the context of the AVE. For example, a supplier chain relies on well-established boundaries to guide the way it integrates into the system. If the supplier were capable of realigning by having shared employees and supervisors (if that were beneficial), it would be more like a Type 1. There is a large class of actions which could be taken to integrate processes. For that reason, Type 3 AVEs tend to look more like Type 1s as they become more agile. Similarly, Type 4s aspire to be Type 2s. Supply *chains* can exist in any of the types.

In our surveys, we found that few real world cases cleanly fit these types. All were some combination; some were more one type in formation and another in operation. In other cases best practice was beneficial because they adopted, for that process, a personality which was of a different type AVE.

11.2 AVE

[Definitions related to agility.]

11.2.1 Definition of Agility

[Agility deals with change.]

A dominant definition of the agile enterprise is one which responds to (and ideally benefits from) unexpected change. Unexpected is a key word; the ability to build in response to expected change in the manufacturing domain has traditionally been termed flexible manufacturing, as distinct from agile manufacturing. But it would be possible to have a flexible enterprise without having an agile one. (The same is true of a lean enterprise.)

The Virtual Enterprise is usually defined as *an opportunistic aggregation of business units which operates in important ways as if it were a single company*. Many versions of the VE exist. Probably a VE is agile only if it is formed with the intent of dissolving or reconfiguring. So it is possible to have a VE without having an AVE.

The Agile Virtual Enterprise (AVE) is an important instance, a model for planning an agile strategy for many enterprises. Obviously, no organization can afford to be ready for all contingencies. A given firm will need to partner with others to bring core competencies to bear in response to unexpected situations.

Each of the four types of VE could result in Virtual Enterprises which are useful but not agile. The AVE is often thought of as one that exhibits a critical number of

characteristics, developed by the Agility Forum, which describe agility. As a rough discriminator, however, a Virtual Enterprise is an AVE if it is formed with the intent of dissolving or quickly and cheaply reconfiguring in direct response to a change in the opportunity.

More particularly, there are a number of conditions which can change and affect an enterprise. An agile response might be required concerning a *negative* change as well as to address a positive opportunity. For example, a positive opportunity would be a newly-identified customer niche, or a leveragable technology. A negative change may be a new restrictive law, a raw material which disappears, or a customer who has been enticed away.

11.2.2 Agility as Creativity

[An agile organization is a creative, learning one.]

Notwithstanding the definition given above, there are a number of other interlocking definitions of agility, each of which has utility to some community. Currently, the Forum uses a concept of mass customization, a more general definition than we address.

We add one more general concept, an intuitive definition: agility as *creativity*. The purpose is not to supplant any of the others, but instead to provide an intuitive equivalent to other characteristics intuitively applied (such as better, faster, cheaper).

An ideal enterprise, virtual or not, is a living, creative entity. It is both self-conscious and also aware of its environment, and it is capable of creatively responding to changes either inside or outside. In this sense, the agility of an enterprise is the capability to be creative.

As the metrics project developed, the nature of the agility paradigm became more clear. A few have known for some time that agility is a radical new paradigm. It represents not an evolutionary new step of another, now well accepted paradigm like lean manufacturing. Instead, it can be regarded as revolutionary.

Being cheaper, better, and faster today is not sufficient to be agile. It can be the case that moves made to make one's enterprise cheaper, better, and faster may make it less agile.

Agility is the ability to change to be cheaper, better, and faster (more profitable) in a dynamic sea of change.

This recognition of agility as a new paradigm is not without consequence. Metrics to work with agility will be a new kind of metric; it just won't do to rely only on existing measures. (Notwithstanding this, the metrics need to map to profitability as defined by the enterprise's strategy.)

It probably is also the case that at least in some situations, the new types of metrics for the new paradigm will require new technology and forms of non-technical infrastructure.

11.2.3 Types of Agility

[Considerations of who is agile, and who benefits.]

Agility of a component in the VE can be analyzed as follows:

- 1. Characterization of what it does
  - 1.a. What it adds to the whole
  - 1.b. What it *makes*
- 2. Characterization of how good it is
  - 2.a. Internal agility
  - 2.b. Internal performance (other: quality, etc.)
- 3. Characterization of how well it partners
  - 3.a. In a static situation (to respond to initial change)
  - 3.b. In a dynamic situation (to respond to continual change)

If one were creating an information base on potential partners, it should gather these six types of information, each with a temporal modifier. The modifier may record how the baseline information is compromised. For instance, normally a partner may be capable of supplying 1000 widgets a month, but they've just booked a big job, so now only have the available capability to produce 500.

Agility can be temporally modified. Say, for example, that the supplier has just entered into an agile situation with Ford. That means that sense-response mechanisms are attuned to the Ford/supplier context. So its ability to be agile in a partnership with GM could be temporally compromised, until the VE with Ford is dissolved.

Overall, there are these four contexts for agility:

- Sum of internal agility of each of the components
- The (probably quite different) agility of the VE as a whole
- The ability of each component to quickly/cheaply aggregate
- The ability of each component to quickly/cheaply change the aggregation boundary

There is a layering here; there are higher and lower orders of agility. It is possible for a firm to be agile internally, but to not be able to agily form a VE, or contribute agility to the VE. If that is the case, the firm may have agility appropriate to its local plan, but it is of a low order.

Much better is the type of internal agility that contributes to *external* agility, agility with your partners. In the four contexts, the following nesting exists, each a dependent subset of the preceding:

- The ability of each component to quickly/cheaply change the aggregation boundary
- The ability of each component to quickly/cheaply aggregate
- Sum of internal agility of each of the components

This is to say that the agility of the VE comes from the ability of each component to be added, or subtracted, and to fluidly change its relationship with the partners, plus the skill of the VE's organizer. (Some will prefer to see the organizer as the VE *engineer.*) So in order to measure agility, we should be looking at the boundaries among components and the internal processes which support them. That is our target for the metrics.

The other contexts for agility are of a lower order. It would be possible to satisfy them well, without supporting the higher orders.

Incidentally, this leads us to a controversy in the agility community. Some hold that agility is something that can mean a great deal, just within a single company context. Others suspect that to be true, but also believe that a much greater reward (more scope at less cost and time) from agility comes only from its VE context.

We've come around to the latter perspective, and now believe that, in any case, agility in the VE context is substantially cheaper and much more effective than internal agility.

11.2.4 Other Agility Definitions

[Our definition is exclusive to change, but others use the term more broadly.]

Whenever a rich idea finds a time that's right, it proliferates in poorly behaved ways. We've seen it in the software community as *object orientation* has caught on and essentially taken over. There are many definitions of what constitutes the approach and its philosophy and on first sight, they're all nearly identical. But the deeper one goes, the more different they seem.

In our studies, we've experienced the same thing with patterns and memes. In each case, there is not a central idea, but a collection of ideas living under one general buzzword. Often there are few real concepts which unite the collection.

Agility is such a rich, timely concept.

We initially had some trouble with the definition of agility because we naively were looking for a single common thread among all the researchers. Instead, we now believe there are three concepts of agility co-existing under the word (and associated sponsored research). All are useful, but to a large degree are orthogonal.

The first definition's central concept is mass customization, and supporting ideas like being close to the customer (providing solutions). Levi's is agile because they can make custom fitted jeans; Mack because a large part of their business is unique trucks. Let's call that A^1.

The second definition, A^2, covers companies which thrive in *change*. But change here is a constant in the environment. It could be seen as changerate, and often is driven by technology. Avionics businesses must be agile because technology development makes products obsolete at an increasing rate. Casio is agile because customers want mouse watches yesterday, waterproof watches today, and lighted watches tomorrow; in this case, the *changerate* is driven by the customer.

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Part 2, Agility Issues

We're using the term changerate, so as not to step on MIT's term, *clockspeed*, and also to make an observation. Clockspeed *can* be interpreted as the rate of the instrument rather than of the phenomenon being measured. In our modest work we've found that both are important. The general case is the speed of the context.

A^1 is a new way of doing business, and probably has the largest pool of enterprises to which it applies. It is revolutionary, if it is a real phenomenon, and there should be lots of opportunity for consulting, assessments and training. Most everyone will want to explore it and many will want to pursue it. The Agility Forum has grown into A^1.

A^2 is a logical evolution of lean for businesses whose changerate is high. Lean was difficult to understand in a meaningful, applicable way; we should expect no less of its future. A large percentage of the agility community are A^2ers, including the university-based centers and projects, in particular the Agile Manufacturing Research Institutes, Arizona State and MIT.

That's good. There is a lot of important thinking going on here. A^2 agility is only of interest to high clock rate sectors of enterprises, probably a smaller group than that which can benefit from A^1. But while the user community for A^2 is smaller, agility is probably essential for their survival.

But wait. Is the future of an agile avionics or missile supplier as they come to terms with changerate in mass customization? Probably not.We think A^1 and A^2 have some overlap, but it is largely an almost accidental and uninteresting result of the fact that most businesses have similarities.

A^2 agility deals with an *expected* and *constant* (or constantly accelerating) type of change. Laptop manufacturers have a high changerate, but the rate of change is predictable (although the details of new technologies are not). It would be possible for a firm to optimize its ability to deal with this expected change and actually lessen its ability to deal with *unexpected* change.

Similarly, A^1 doesn't help with unexpected change or opportunities. Mack Truck is considered A^1 agile, but can it make money supplying major subassemblies to Caterpillar when a construction boom hits? Can they easily leverage a core competency in truck cab sleepers to move into combat tank sleepers if an opportunity hits?

The money for Levi's may not be in jeans, it might be in custom measuring of shoes, or something else. They could be surprised by what the opportunity is. Does furthering A^1 or A^2 increase their ability to change in these unexpected ways?

We can easily invent examples where A^1 and A^2 act against this adaptability. There is a third kind of agility, A^3, which concerns itself with adaptability, the ability to change when an unexpected opportunity appears, or if the earth shifts beneath your feet.

A^3 has a much smaller community for whom it is a major concern: most businesses never know the opportunities they miss and few believe in buying insurance against change until it is too late. This is the most revolutionary agility. Certainly

it has the most challenging set of problems; measuring an ability to adapt, to learn, is no easy matter.

A^3 is of concern in the defense sector. We know we need to counter a threat, but we know neither what the threat is nor what technology will be available. And we have found many in the civil sector who are looking for A^3 agility without necessarily calling it agility.

Our metrics are in the A^3 area, and it is only in that area that the metrics apply. It is our view that Rick Dove's early work [DOVE95], and Kenny Preiss's work on dynamically coupled systems is pure A^3. [PGN96]

There are three relatively unrelated concepts each with their own, independent act under the agility bigtop. This realization has helped us a lot in interrelating the various research efforts.

11.2.5 Role of the Organizer

[One partner is an organizer, who has additional agility concerns, how agily it can organize or coordinate organization.]

The competence of the organizer is key to the general success as well as the agility of the VE. While the organizer is often a *prime*, there is no requirement for this. It could be a minor player in the operation, or someone with no role in the operation, such as a broker or consultant.

As noted, agility in the VE is dependent on the contributions, of different types, from each of the members. But it also depends on the special ability of the organizer to engineer and manage that potential.

The other players have one set of metrics for how agily they can be organized. The organizer may have another set pertaining to how well it can organize an AVE. This will be a partnering consideration for everyone involved, because surely an indicator of success is the strength of the VE integrator.

These organizer metrics are not difficult to understand and use: they'll be similar to, and in most cases identical to, metrics which currently are used to evaluate the ability to engineer or re-engineer an organization. Our metrics will not directly measure this organizer's ability. We measure the potential that is there, but not the manager's ability to maximize that potential.

It could be that there is no central entity that is the organizer. Perhaps the organizing entity is itself a virtual entity composed from several sources which may or may not be involved in the operating VE. Perhaps the entities are self-organizing, the *organizer* being diffused in rules. Some Silicon Valley VEs are of this type. The Whaling example has some elements of this type.

An interesting case is when the *customer* is the organizer. Naturally, the options listed above are available. Any of these cases can be ideal from a market responsiveness point of view, assuming that the customer is the best judge of what is needed. (But there is ample evidence that this is at least not always the case.)

Part 2, Agility Issues

We've noted that the Defense AVE is unique in the role that the customer (meaning the DoD acquisition manager) plays in the AVE. This is the sole area in which the commercial and defense AVEs differ. Because of the importance of the Defense AVE, we will further explore some of those organizer issues.

11.2.6 Types of Change

[Different changes require different types of agility.]

The metrics must have two parts: the *context* of the change and a measure of the *effectiveness* of the strategy to respond. Usually, change is categorized into the following five groups, often associated with a state diagram:

- Resources
- Technology
- Processes (internal conditions and mechanisms)
- Environment (external conditions and mechanisms)
- Demand (customer conditions and mechanisms)

Often, agility is considered in the context of change in the customer base. But we've discovered a larger set of contexts of change. It's assumed that we need to measure agility in any of these five categories, and that there is no particular level of importance.

We've changed this model to consider technology as a *resource*. This is because, for our target customers, agility is not a response to technological innovation, but instead is a business response which might be empowered by technology. The assumption doesn't ignore technology, but requires that it always be evaluated as a resource.

A minority objects to this view. It is easily demonstrable that technology is the major driver of change. We agree. Technology in this model refers only to technology which *supports* the enterprise. This use of technology has not traditionally been a driver of change except in the context of the other factors. For example, technology empowers certain types of customer demands.

The boundaries among the last three (processes, environment, demand) may indicate a difference between agility in the virtual enterprise and in the non-virtual enterprise (single firm). In a single firm those boundaries are solid and well understood. In the VE those boundaries (and possibly those of resources) are blurred and movable. At the least, it's assumed that internal and external conditions and mechanisms have no real boundary and instead represent a spectrum.

So one set of metrics will address the ability to move boundaries beneficially in a VE: for example,

- to make an external resource internal
- to harmonize an external disruption by incorporating internally (to empower unions in the enterprise, for example), or
- to damp customer oscillations by bringing them into the enterprise in some way. These would not apply to the non-VE case.

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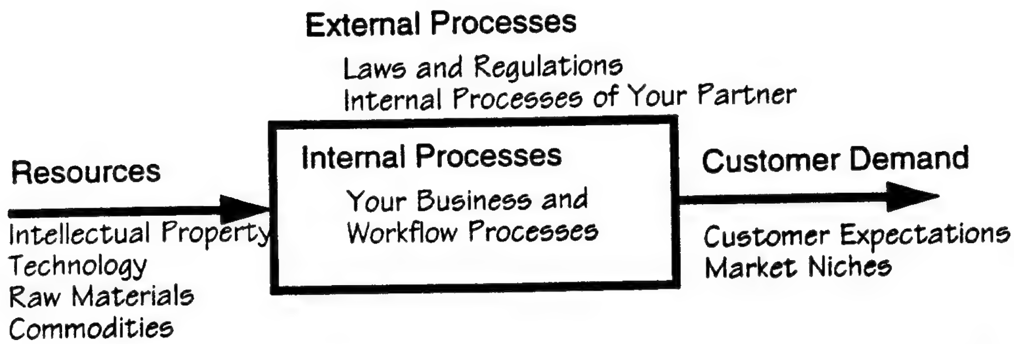

Figure 11-2:Unexpected change (positive or negative) can come from any of the four key areas

		A Positive Example	A Negative Example
Unexpected Downstream	**Customer Behavior**	New Niche Identified	Customer's expectations change
Unexpected Upstream	**Material Change**	New Raw Material	Disastrous Loss of Raw Material
Unexpected Internals	**Process Change**	New Process Developed	A Key Expert Retires or Dies
Unexpected Externals	**Regulation/Partner Change**	New Competitive Tools	New Regulatory Demand

Table 11-1: Some Examples

It is also evident that agility may be pursued for some strategic reason that is not prompted by an external or uncontrollable change. Perhaps some strategic reason appears, for example, one might want to move agily to partner with a company to prevent their abilities from going to a competitor. While this would fit in the above view, it would not appear if the only driver were cost and time.

12 Metrics

[Considerations relating to what the metrics themselves are.]

In other sections, we've defined what constitutes a VE, what agility is and what it isn't. We now turn to the nature of the *metrics* required to address the engineering of AVEs. This section breaks down the various characteristics required of the metrics to support that engineering/management process.

12.1 What Are We Measuring?

[We don't measure what you did, but what you are (likely) capable of doing.]

The term *metrics* is applied to a number of situations. What do we mean?

To others, a metric is a measure of improvement. In this case, some technology and/or management technique is brought to bear to accelerate the change. Retrospectively, one observes that some element of the VE is improved, for example, partner selection is speeded, or engineering change processes are reduced. The comparison of the improved situation with a similar, but unimproved one results in a measure of effectiveness. This is a *retrospective* measure. We do not address this situation.

At the shop floor level, the term is often applied to characterize the performance or envelope of a given equipment or cell. Thus there are a class of metrics which track improvements on processes which managers routinely use. Many *quality-related* metrics are of this type. Our metrics are not the same as these, but there are similarities to many of these metrics that are derived not from observation, but by exercising some model of the process and are *parametric*.

Another class of distinctly different metrics are metrics that measure the cost, time, and quality of processes not associated with change. An example is the metric which measures the time-to-market. Another class of metric deals with how cheaply, well, and fast an enterprise or VE can do things. Our metrics, which only measure the time and cost of *change*, will be combined with these base case better-faster-cheaper metrics to determine the total time and cost associated with the whole system under conditions of change.

So if a company merely improves its existing processes, which it might consider as a change, our metrics would not apply, since we do not consider a refinement of a process an ability to respond to change. In fact, by our definition, no agility measure applies.

In another case, if a company exhibited agility in the past in response to change, our metrics still might not apply, since past agility indicates nothing or very little about *future* agility.

Our metrics address only the time and cost associated with the *potential* that a system has to accommodate *future* change.

12.2 Upstream Metrics

[We measure in a fashion that can indicate what needs to be done to improve agility.]

The kind of metrics the AVE needs are *upstream* metrics rather than *downstream* metrics.

A *downstream* metric is the conventional kind, related to *benchmarking*. It looks at a process and extracts some performance measure from it for example for monitoring the process. When the measures are compared to a large body of similar processes, one process can be benchmarked against the others, and management decisions made accordingly. But *continuity* in the context is essential.

Downstream metrics don't convey knowledge about the internal workings of the process, so they cannot tell one how to *improve* the process, only that the process needs to change somehow to improve the *number*. Moreover, since there is an assumption that the future will be extrapolated from the past, they tell us little about adaptability in a *new* context.

Upstream metrics are based on the internal mechanics of the process. An understanding of the metric is based on the understanding of the process. Upstream metrics can answer questions that a manager/planner may have about how to improve the process.

There is a precedence for these kinds of metrics in manufacturing based on an engineering analogy applied to physical processes. The project applied this method across all of the elements in the VE associated with agility and identified by the Reference Model. This will be done by understanding the causes and effects of agility, as if models of the system were simulated.

As with upstream and downstream metrics, there is a similar division with the models that support them.

Some models are used to only *evaluate* the enterprise, or some part of it. The analysis is performed and the model is discarded, unless of course the analysis is continuous and the model must be maintained. But there is a more robust class of models, those used to actually *control* the enterprise. There is a relationship between the control model and our upstream metrics. The best situation would be for us to directly work from and contribute to the control model.

Some have confused this notion of upstream metrics with metrics of *leading indicators*, common in process industries. But it is a much more powerful idea; leading indicators only give you a warning of impending change assuming that your experience base is robust and conditions are known. But the do not tell you *why* things will change.

12.3 Necessary Conditions

[We do not assume that there are any agility strategies that fit all conditions.]

Some agility metrics might be based on *necessary* conditions. But we intend to extract those conditions as a result of the principles involved and their metrics, rather than the other way around.

For example, some contend that flat organizations are necessary for agility. Based on that assumption, they derive a measure of flatness and apply it to agility.

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This is the case of a class of metrics often used by the agility community, in our opinion mistakenly.

Instead, the metrics project came to a more basic understanding of what really results in agility. One would expect that in many situations, the resulting metrics would advise flattening of the organization. But the *exceptions* to this rule of thumb are many. How would you know whether they apply to you if you didn't know how it produced agility?

Insight into actual processes would emerge by applying the metrics. More importantly, a chain of logic would be established that helps justify high confidence decisions.

12.4 Dynamism of Metrics

[These metrics are hard because they measure the control over dynamic coupling. Agility is like insurance.]

Most metrics are *static*. They report on a factor in a snapshot sense.

Agility is a potential to make *change in response to change*. It reports on a capability that projects current capabilities in today's context into a new set of capabilities in another context. Therefore, the metric will be dynamic.

All such metrics will be collections of interrelated numbers. One collection will convey the dynamic nature of the changing capability. Another will show how that collection can be accelerated or delayed at different costs and for different times. Because of this, there may be a concept of acceleration or *inertia*.

In other words, the metric takes into account the *running start* an enterprise may have.

Agility metrics are different than many other metrics in the manufacturing enterprise. Flexible, Lean, and Quality paradigms, for example, presume that there is always a better level of flexibility, leanness, or quality which would help the enterprise. The optimum level is a trade-off between better quality (for example) and its marginal cost.

Agility follows this rule to a point. In ways that an enterprise needs agility, there is always a cost/benefit balance that metrics can inform. But there is another set of trade-off points, where further levels of agility are not good, and in fact might hurt an enterprise's strategy.

Agility is insurance, and investment decisions need to be made accordingly. It is possible to have too much insurance (or the wrong kind). The ability to accommodate a change that is unimportant or unlikely to occur represents the wasting of resources. So where quality mavens can say that there is never too much quality, we cannot say the same for agility.

12.5 Difficulty of Benchmarking

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[The metrics bear no relation to benchmarking measures. Agility may not be benchmarkable.]

Elsewhere, we have distinguished between upstream metrics and downstream metrics. Examples of downstream metrics were benchmarks. The intended mean-

ing of *benchmark* there was an after-the-fact snapshot metric whose utility is in comparing to other snapshots. In making the distinction, it was assumed that upstream metrics are more difficult because they require insight into the actual processes involved, whereas downstream metrics do not.

But there is a more fundamental difference, not captured earlier. Agility is defined as the potential to respond well to *unexpected* change. Any metric that is useful tracks that potential. A downstream metric can do no better than measure how well a process (or an enterprise as a collection of processes) responded to a specific change.

So a downstream metric might have some utility for application to a process in order to benchmark it against itself. But in order to be useful to another process in another organization, a thorough normalization must take place, making sure the process and the general context is similar between the two cases, including the specific unexpected change.

Here's where we run into difficulty. Benchmarking as commonly applied is the process of comparing many companies, identifying the best in class, and then presumably comparing your organization with the purpose of improvement. Some benchmarks indicate the process to change, but most don't give insight into the actual mechanics of the change.

Benchmarking assumes that there is a well understood set of characteristics that are being benchmarked and that there is a meaningful sample size. Unfortunately, many people are under the impression that various lists from the Forum constitute that set of characteristics. Instead, those lists contain either characteristics that people think are likely to coincide with agility, or that were results of agile action.

Examples of the first are *modular processes*, *flat organizations*, *empowered individuals*, etc. It may be that implementing these characteristics may generally make most enterprises more agile, but it is also clear that these are not the primary engines of response. Examples of the latter are the ability to retool a particular piece of equipment. So we lack the prime starting point of conventional benchmarking.

Elsewhere it is noted that more agility is not necessarily better. The conventional benchmarking paradigm assumes units where the case with the most units is best in class.

All of these perspectives on agility suggest that agility is a paradigm that falls outside of the scope of paradigms that can be addressed by conventional benchmarking. In particular, agility is the ability to *react*. Any measure of reaction must capture the context (ideally itself in measured units) of the situation to which the enterprise is reacting.

Instead of conventional benchmarking, agility must look for a better way of accomplishing quantitative assessment, one that understands both the context (which might be unique from case to case) and the effectiveness of the response.

It is an open issue whether there is any such thing as a downstream metric for agility which differs in substance from the upstream metric. This is probably the same question as whether the upstream metrics of this project are sufficient for a

new paradigm of quantitative assessment. We think probably not, but in any case quantitative assessment to satisfy the benchmarking agenda is outside of the scope of our approach. All downstream metrics are probably going to measure the effectiveness of the tactic used to respond and not the strategy which drives it.

12.6 Two-part Metrics

[Each response has to take into consideration the nature of the change to which it is responding.]

The project is geared toward providing a single generic metric type, and guidelines (and examples) for tailoring them to specific processes via the Reference Model where information about agile decisions is desired. All of these generic and specific metrics will be two-part.

The first part will characterize the *context* in which the agility is posed. The second, more simple part characterizes the *response* in cost and time. In other words, agility is the ability or capability to change well (in terms of cost and time) in a given set of conditions. So the project has always to provide the measure of the response in the context of a measure of the stimulus. This will allow for connection with simulation as well.

The *context* problem raises many vexing problems, owing to the diversity involved. The project gets a handle on context by relying on a close understanding of what discrete infrastructure mechanics are involved. It may be that many of the contexts are characterized in terms of constraints.

Two of the established concepts to understand agility are scope and robustness. Scope refers to how large a domain is covered by the agile response system. In other words, how *far* from the expected set of events can one go and still have the system respond well. The other concept, robustness, is a measure of how well the system responds, given a specific scope. These two go together naturally.

They can be envisioned as a three-dimensional bump on a plane. The plane represents the universe in which the system operates. The height of the bump is the robustness of the system. The nature of the peak is not of interest here, but as one gets farther away from the peak, the system's designed focus, the robustness tails off and becomes flat.

The project characterizes several characteristics of this hill. But in almost all cases, the width of what can be addressed within/by a single company is vastly less than can be addressed if VE-type partnering is agily available. Both the height and area covered are very much greater (over an order of magnitude on some scale) greater if the *VE* is part of the agility solution.

Therefore, we believe that the more interesting case for understanding and harnessing agility is the *AVE context.*

12.7 Quantitatively Scalable

[To be useful, the metrics need to be numbers calculated from the process, not subjectively determined.]

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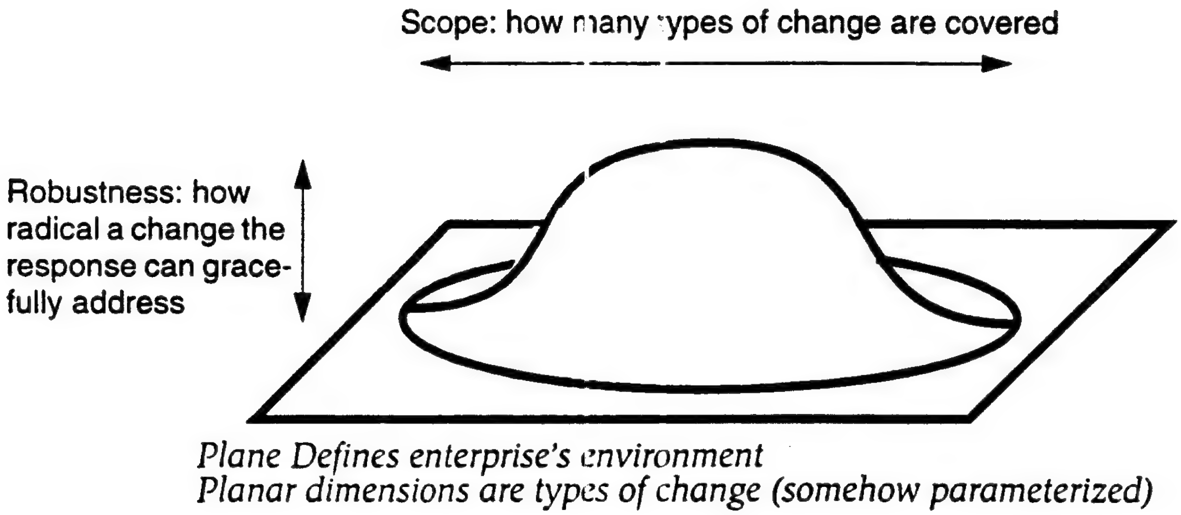

Figure 12-1:The parameterized agility of an enterprise can be seen as a curve over a plane

The metrics are *quantitative*, that is, naturally based in numbers. This contrasts with *subjective* evaluations which currently characterize the study of agility.

They are formally based, meaning that there is a well-established link with the management and information sciences involved. Different persons evaluating the same process using the same methods will produce identical values.

These values are denominated in standard units which are commonly used and carry intuitive value to the manager. An unsophisticated manager can understand the metric, while a sophisticated manager should be able to audit the underlying mechanics all the way to the enterprise's strategic measures of profitability and strength.

We can distinguish three concepts of scaling in the metrics.

- The metrics of interest are not process-dependent, nor linked to any specific granularity of processes. In other words, it should not matter whether the metric is applied at the level of an individual process (fine granularity) or at a coarser level such as a cell or line. The square feet metric as an indicator of lean is a good example: it applies equally from the individual process to the factory; the fewer square feet a process has the more lean it is.

  A example of a metric which does not scale is quality. The sum of many quality processes does not necessarily result in a quality system.
- Second, the metrics scale horizontally as well, across functions. It is useful that the enterprise can be evaluated by the same metrics regardless of whether it is a shop-floor process or an administrative service.
- Third, the metric is internally linear, without discontinuous thresholds. In other words, the difference between a 3 and a 4 is the same as the difference between

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a *4* and a *5*. It should not be the case that at some threshold within an interval, the improvement is radical.

Of them, the first is most important and the others are highly desirable.

In addition to the caveat noted above, there may be a barrier to the scaling when the process leaves the individual corporate boundary of the individual entity. For example, square feet as an indicator of lean may become relatively meaningless when applied collectively to several companies in VE partnership.

This is to say that there might be different metrics or constraints used to measure agility of a component than to measure the agility of the VE. In particular, the following types of measures may be used:

- Metrics of agility within a component (a partner);
- Metrics of the agility the component brings to the VE;
- Metrics of the agility of the component within the VE; and
- Metrics of the agility of the VE seen as a whole.

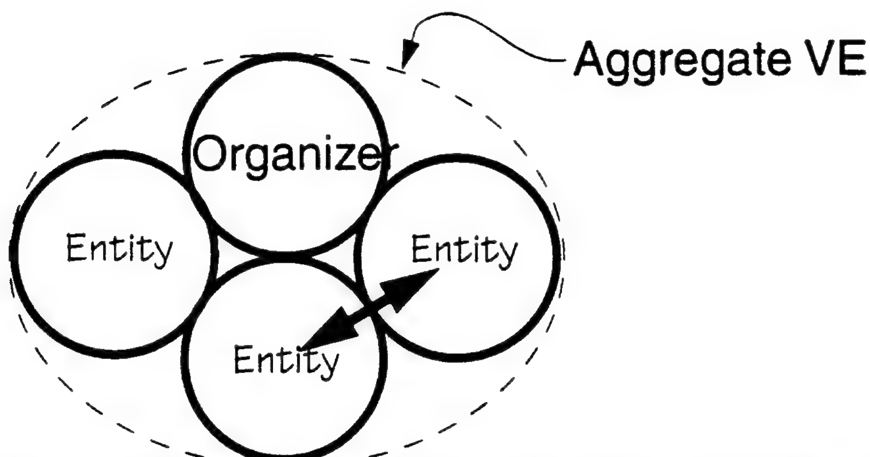

Figure 12-2:Agility Within Entities, Among Entities, and of the System

Because of the above differences in focus, there may be a different set of metrics or a different context to metrics used by the organizing entity than by partners being organized.

In particular, the scaling limit is probably traceable to when the representations of the features which characterize agility (transactions) are turned into numbers. In the tactical case, the numbers themselves are useful. But a simple combination of the numbers does not convey the same amount of information as a combination of the representations which underlie them. This is the traditional systems optimization problem: a simple sum of agile components may not result in an agile system.

This is why we use a scenario-based conversation breakdown to capture two elements of agility for a process in each Reference Model's cell: the intrinsic agility of the process, and the agility contribution to the system.

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12.8 Legacy vs. Heritage

[An optimal agile response not only accomplishes the change, but does so in a way that increases your agility for the next time, probably different.]

The nature of agility is *anticipatory*. Where cheaper, faster, and better deal with the situation today, agility (and its little brother, flexibility) deal with the situation (ability to be profitable) tomorrow. Naturally, the focus on the ability to change turns into *profit today* very quickly, how quickly being a part of the metric.

The relationship between *profit* today (as captured in lean manufacturing for example) and *agility* tomorrow is an interesting and complex one. A similar relationship exists between *legacy* as opposed to *heritage* infrastructure.

Usually, the re-engineering process converts the *as-is* situation, often called a *legacy*, into a *to-be* system. Under this view, the legacy represents a barrier, a collection of problems. Once the as-is becomes achieved, all will be well. But agility deals with establishing the capability to change to a large and constantly changing set of as-is conditions.

It is useful therefore to define two classes of legacy: the legacy which exists before a re-engineering change is made (using the new term, *heritage*) and the legacy which exists afterwards.

The *heritage* is what you inherit from others, for better or worse. Much of the game involves identifying strengths and weaknesses in this heritage and developing an appropriate strategy. A *legacy* is the heritage that you create for the future, the next folks, with its own strengths and weaknesses. Ideally, the legacy you leave will be more self-aware and capable of leveraging itself than the heritage you are given.

The metrics of the project are targeted toward understanding the heritage in such a way to improve the legacy in its ability to change itself beneficially.

12.9 Environmental Drivers

[There likely are some external conditions within which enterprises and partners exist that will tend to make them more agile than without those conditions.]

The metrics of course advise decisions. But one would expect that they would indicate generic strategies as well. For instance, it seems to be a tenet of VEs that (under normal circumstances) capital investment should be focused on core competencies and away from skills that can be obtained by partnering. The metrics should reinforce and clarify the limits of obvious principles such as these, but they should also indicate less intuitive general principles.

One secondary area where general principles would be useful is in the area of a *VE Promoting Environment*. Clearly, some *environmental* factors can make it easier for the type of partnering that drives interesting VEs. Such environmental factors spontaneously appeared to support the whaling industry and may be in place today to some extent in Silicon Valley. It is not the purpose of the project to understand these dynamics; perhaps a follow on effort by others is indicated. But

certainly, the behavior indicated by the metrics should shed light on the nature of this environment.

For example, much has been made of the legal difficulties associated with the VE. Some maintain that legal barriers are intransigent limiters, preventing interesting Type 1 AVEs from forming. These people maintain that a necessary condition for a VE Promoting Environment is the legislative resolution of these and related issues (such as intellectual property rights and security).

We would expect the metrics to help indicate alternative approaches to these seemingly insurmountable barriers. Early thinking has already indicated some example threads worth following in the legal infrastructure.

The standard response to VE legal agreements is to try to generate generic, *plug and play*, *instant* contracts. But it is clear that such instruments either will be overly restrictive in the business relationships, or obese. The FAR (Federal Acquisition Regulations) were generated with just this lofty goal of an instant, generic contract in mind. Such thinking is dragging federal acquisition back to the middle ages.

Instead, suppose one focused on a set of ethical principles for arbitration. If these were solidly, simply based, they could form the basis for resolving issues as they arise, instead of resolving all possible issues ahead of time. This tactic could allow for VE-empowering lightweight agreements. It is also a tactic that the U. S.'s significant international competitors cannot implement as well because we use case law instead of their code-based laws. Case law is based on this tradition, but has been obscured. The whaling example reinforces this point).

Another, related problem deals with trust. Often, the primary purpose of a *heavyweight* contract is to mitigate distrust, and a large component of that deals with liability. In fact, the issue is who has to pay for liability insurance (either explicit or internal) to cover which conditions. The legal barrier here actually resolves to a technical requirement. What is needed are VE-sensitive actuarial tools to empower a VE liability insurance business. Probably, this would allow the insurance company to become a member of the VE.

12.10 Strategic Links

[The metrics need to support the differing parameters used in strategic planning. Those are noted.]

All intelligent enterprises will have a strategy, which represents a balance of profitability today and profitability tomorrow. The latter is a measure of strength and will be a mix of the following:

- Customer Goodwill
- Core Competency Development
- Intellectual Property
- Market Share
- Employee Development
- Stockholder Value

(Each of these has dependencies with the others.)

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In the future, Agility will be added to this list. Until it is, every metric that is developed in the project must have a direct chain of logic from the individual application of the metric to either immediate profitability or some mix of that and the six listed above.

Early in the project, it was thought that this chain of logic could be shortened. The reason is that the top level metrics (profitability and the six strength metrics) would have already been supported by a strategy. The strategy would have been supported by a set of *strategic* metrics.

Strategic metrics are of the type:

- Correct Product
- Cost
- Quality
- Cycle Time.

Since the logic chain was presumed to exist between these four and the *top level* metrics, it seemed sufficient to make the new agility metrics relate only to the four.

But it has subsequently been determined that agility is substantially different than the static strategies which support the four strategic metrics. This difference is discussed elsewhere.

(The sequence of Correct Product, Cost, Quality, and Cycle Time represents the historical sequence that these have become accepted as useful strategies. The metrics applied are listed in the same sequence elsewhere: cheaper, better, faster.)

So the challenge is to provide a clear chain of logic from each of the new metrics, all the way up to the top level profitability and strength metrics.

12.11 Rules of Thumb

[Repeated use of the metrics will result in some rules of thumb that won't need the expense of calculating numbers.]

We believe that many decisions that a manager encounters will be identical or similar to situations encountered by others. After a period of time and experience with the metrics, certain *rules of thumb* will emerge. We consider these rules of thumb to be among the best potential long term products of the project. Managers can apply these rules of thumb without going through the effort of evaluation by the metrics.

We expect the Agility Forum to provide a service to the domestic economy by collecting these rules of thumb in an easily accessible case base.

Many smart people have been meeting and talking about agility for some years now. Some intuitive results have emerged. For example, many people feel that the more flat an organization is, or the more empowered the work force is, the more agile the enterprise will be. This is probably true in many cases, but clearly not in all cases.

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Application of the metrics would be expected both to verify these intuitive suspicions and (more importantly) to indicate the scope within which they apply, and the limits of application.

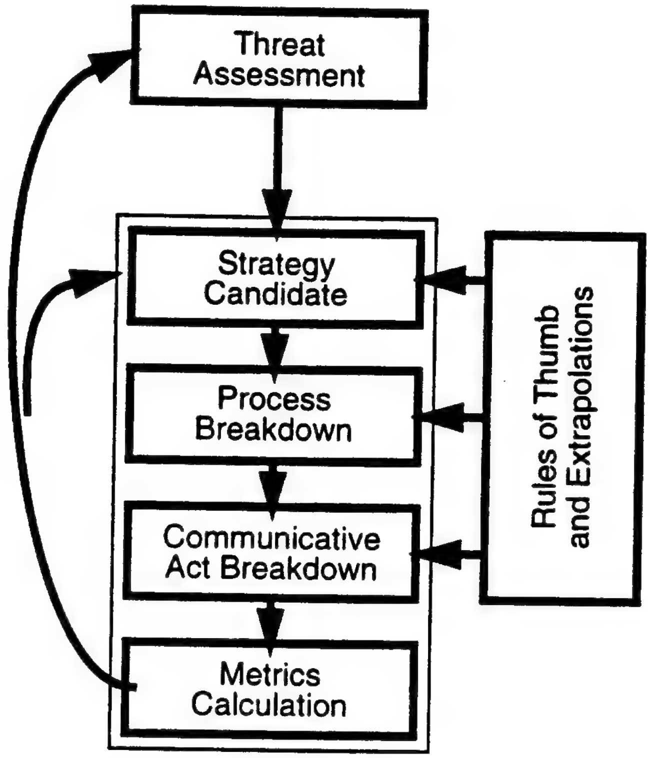

Figure 12-3:Rules of Thumb Can Be Extracted from Several Steps in the Process

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Part 2, Agility Issues

13 Agility and Other Approaches

[There are other beneficial trends underway. How does agility relate to them?]

13.1 Agility Forum and A^3 Agility

[Our work complements that of the Forum without much overlap.]

We use traditional Agility terms where appropriate. But it is important to note the few differences that might exist with assumptions of prior work and work by others.

The Agility Forum over the past four years has developed different sets of descriptive terms for agility. Some of those sets are more popular than others. It might be beneficial for our metrics if straightforward links with those terms and concepts were made and we have done so below. It certainly will register the metrics better with those accustomed to using those terms.

Problems arise, since the many existing terms are general and not formally definitional. That is, it is possible to find examples which fit all the terms but are not examples of A3 agile systems.

In one set of definitions [PGN96], the Forum uses the following four characteristics to define agility:

- Solutions Provider
- Collaborative Production
- Reconfigurable Organization
- Knowledge-Driven Enterprise

These characteristics don't discriminate between agile and non-agile cases with sufficient crispness on which to base the formal metrics studies. Therefore, we've defined here our view of agility which could be considered pure agility, A^3, which we think is a subset of what the Forum has taken as its charter. The difference, we believe, is simply that we've avoided the many good business practices that are not unique to agility, *the ability to respond to change.*

Nonetheless, the AVE Focus Group worked to make a mapping from the *Life Cycle Dimension* of the AVE Reference Model to descriptors that the Forum has developed for A1 Agility:

- 1.1 Opportunity Strategy
    - Intensifying Competition
      Rapidly Changing Markets
      Increasing Capable Communication Technologies
      High Rate of Innovation
      Decreasing New Product Time-to-Market
    - Fragmentation of Mass Markets
      Growth of Niche Markets
      Shrinking Product "Windows"
    - Cooperative Business Relationship

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- Increasing Inter-Enterprise Cooperation
- Increasing Outsourcing
- Global Sourcing/Marketing/Distribution
- ♦Solutions Provider
- Niche Marketer: High Product Density
- High Product Introduction Rate
- Rapid Concept-to-Cash
- Production to Order
- Solution-Based Marketing Policies
- ♦Adaptive Organizations
- Coordinated, Decentralized Decision-Making
- Change Proficient Organization
- ♦Knowledge-Driven Enterprise
- Dynamic, Competency-Based Strategic Plan
- Enterprise-Centered Operations
- Open Information Policies
- Open Communication Policies

♦1.2 Exposure

- ♦Cooperative Business Relationships
- Increasing Inter-Enterprise Cooperation
- Interactive Value-Circle Relationships
- ♦Solutions Provider
- Proactive Marketplace Change Agent
- ♦Collaborative Operations
- Collaboration = Product Strategy of First Choice
- Electronic Commerce Operability
- ♦Cooperation
- Cooperation with Suppliers
- Cooperation with Customers

♦1.3 Targeted Marketing

- ♦Cooperative Business Relationships
- Increasing Inter-Enterprise Cooperation
- Global Sourcing/Marketing/Distribution
- ♦Demand Identification/Creation
- Market Research
- Product Definition
- Product Feasibility: Realization Strategy
- ♦Adaptive Information System

♦1.4 Search

- ♦Fragmentation of Mass Markets
- Growth of Niche Markets
- Shrinking Product Lifetimes

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- Cooperative Business Relationships
  Increasing Inter-Enterprise Cooperation
  Interactive Value-Circle Relationships
  Increased Outsourcing
- Increasing Societal Values Pressure
  Regulatory Environment
  Workforce Education
  Changing Social Contract
- Adaptive Organizations
  Timely, Opportunity-Driven Organization
  Adaptive Information System
- Knowledge-driven enterprise
  Corporate Knowledge Capture
  Open Information Policies
  Open Communication Policies

- 2.1 Partner Qualification
  - Cooperative Business Relationships
  - Solutions Provider
    Cost-Effective Low-Volume Producer
    Production to Order Individualized Products/Services
    Life Cycle Design Methodology
    Open Architecture Product Design Philosophy
    Extraordinary Quality Standards
  - Collaborative Operations
    Cooperation = Product Strategy of First Choice
    Concurrent Operations
    Integrated Product and Process Development
    Virtual Organization Partnering
    Electronic Commerce Operability
    Proactive Information Sharing Policies
  - Adaptive Organizations
    Timely, Opportunity-Driven Organization
    Change Proficient Organization
    Adaptive Information System
  - Knowledge Driven Enterprise
    Open Information Policies
    Open Communication Policies
  - Integration
    Real Time Management Tools
    Comprehensive, Distributed Information Access
    Support for Physically Distributed Teams
  - Flexibility
  - Enterprise Management

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- Supplier/Customer/Partner Relations
- Knowledge Assets
- Information Systems
- ●Metrics
- Rapid Partnership Formation
- Pre-qualified Supplier Certification

●2.2 Partner Performance History

- ●Solutions Provider
- Extraordinary Quality Standards
- ●Collaborative Operations
- Virtual Organization Partnering

●2.3 Partner Search

- ●Enterprise Management
- Supplier/Customer/Partner Relations
- Human/Physical/Financial Resources
- Knowledge Assets Information Systems
- ●Collaborative Operations
- Virtual Organization Partnering
- Electronic Commerce Operability

●3.1 Vision/Strategy Development

- ●Intensifying Competition
- ●Cooperative Business Markets
- ●Fragmentation of Mass Markets
- ●Solutions Provider
- ●Collaborative Operations
- ●Knowledge-Driven Enterprise
- ●Integration
- ●Cooperation
- ●Enterprise Management
- ●Demand Fulfillment
- ●Metrics

●3.2 Partner Criteria and Selection

- ●Collaborative Operations
- ●Adaptive Organization
- ●Integration
- ●Cooperation
- ●Enterprise Management

●3.3 Enterprise Metrics

- ●Knowledge-Driven Enterprise
- ●Integration
- ●Enterprise Management
- ●Metrics

- 3.4 Capitalization
  - Enterprise Management
- 3.5 Product Liabilities
  - Knowledge-Driven Enterprise
  - Integration
  - Cooperation
  - Enterprise Management
- 3.6 Risk/Reward Strategies
  - Collaborative Operations
  - Knowledge-Driven Enterprise
  - Integration
  - Cooperation Enterprise Management
  - Demand Fulfillment
  - Metrics
- 3.7 Operating Structure
  - Collaborative Operations
  - Adaptive Organization
  - Knowledge-Driven Enterprise
  - Integration
  - Flexibility.
- 3.8 Dissolution
  - Cooperative Business Relationships
  - Adaptive Organization
  - Reconfigurability
  - Enterprise Management
  - Metrics
- 4.1 Performance Measures
  - Collaborative Operations
  - Adaptive Organization
  - Knowledge-Driven enterprise
  - Integration
  - Cooperation
  - Enterprise Management
  - Metrics
- 4.2 Customer Relations
  - Cooperative Business Relationships
  - Solutions Provider
  - Collaborative Operations
  - Knowledge-Driven Enterprise
  - Cooperation
  - Enterprise Management

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- Demand Fulfillment
- 4.3 Operating Practice
  - Cooperative Business Relationships
  - Solutions Provider
  - Collaborative Operations
  - Knowledge-Driven Enterprise
  - Cooperation
  - Enterprise Management
- 5.1 Identification of Need
  - Solutions Provider
  - Collaborative Operations
  - Adaptive Organization
  - Knowledge-Driven Enterprise
  - Integration
  - Cooperation Enterprise Management
  - Demand Identification
  - Demand Fulfillment
  - Metrics
- 5.2 Residual Liabilities
  - Knowledge-Driven Enterprise
  - Enterprise Management
  - Metrics
- 5.3 Asset/Equity Dispersal
  - Enterprise Management
  - Knowledge-Driven Enterprise
  - Metrics

13.2 Older Agility Forum Work

[Our work also complements a separate, earlier thread of the Forum's, with a little more overlap.]

Another legacy of agile terms has come from the Forum-sponsored Best Agile Practice Survey of 1994 [DOVE95]. This vision deals primarily with manufacturing processes, tools, and resources. Social and business process issues exist only to support change in those domains. The view is fine-grained, focused on individual items, practices, and tools. An implicit assumption in this vision is that agility is additive; a sum of agile tools and methods will result in an agile enterprise.

We look at the broader context; agility concerns any type of enterprise, though manufacturing is the most interesting. Its scope includes very early phases in the opportunity, and continues as late and as deep as the enterprise reaches. It includes all processes, not just those related to manufacturing. This vision looks for systemic principles and concerns itself with agile infrastructure.

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A useful exercise will be to reconcile these two approaches through the metrics. As a preliminary step, the terms of the Forum's Best Agile Practices vision need to be redefined in the context of our results

The best practices study used four dimensions of agility. These describe end benefits. They are:

- cost
- time
- robustness
- scope

We find great value in these, but do not consider the four items as being in the same class. We've heard strongly, from our potential user base, that agility metrics need to be in terms of the time and cost of effecting change. The other two dimensions are part of the descriptions of the context. In other words, we expect that a manager will ask, given a specific context (which includes scope and robustness), what is the time and cost of a specific change.

Time and cost are related by a function, so one of these will also be a constraint, depending on the situation. For example, the manager may actually want to know that they have to change within a specific time period and context; tell them the cost. Our use of the term *context* is intended to subsume scope and robustness. Context is the characterization that is determined by strategic studies that specify the type and extent of agility of interest.

For example, one context may be the agility associated with supplier contract arrangements, the scope being the ability to change from a specific small number of contracted units to a larger, specific number. We might be interested in the agility of that context. But if the larger number were twice as large, a different scope, a different agility metric would result. (Incidentally, we've discovered that some things which are agile in one scope are comparatively less so in a different context.)

With this understanding of scope, the time and cost function captures the notion of robustness.

A second set of legacy characteristics from the Best Agile Practice Study is called the eight change domains of agility. These describe characteristics of agile tools and methods. They are:

- creation
- capacity
- capability
- reconfiguration
- migration
- performance
- improvement
- recovery

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Our metrics do not use these as definitional of agile systems. Instead, we understand these to be expected characteristics in certain situations as brainstormed by bright people based on intuition. In their place, we expect that rules of thumb will appear from use of the metrics. These should mirror and validate the cited change domains but with the applicable context.

The AVE Focus Group has mapped the Forum's agility attributes to the Reference Model.

13.3 Virtual Manufacturing

[We particularly support simulated AVEs.]

One definition of *Virtual Manufacturing* (VM) is the strategic simulation of many options within a manufacturing enterprise to support decisionmaking. (Another definition looks at fine-grained manufacturing processes and their simulation individually for local optimization.)

Clearly, our metrics work overlaps the enterprise-wide view. Historically, an interest in VM was what led us to the metrics project. In particular, the metrics are projective. That means that the projection is based on rules, extrapolation, or simulation. The latter case is a working definition of VM developed by an Air Force Manufacturing Technology industry workshop: *VM is the use of simulation to determine performance and change via high confidence models with parameters.*

We feel that these metrics will provide a missing foundation for VM.

13.4 Activity-Based Costing

[Activity Based Costing is irrelevant to agility.]

There is quite a controversy concerning *Activity Based Costing* (ABC) and agility. Some believe that ABC is especially well suited to support agility, and there have been DARPA Agile Research contracts let which support this view. But from the perspective that has been emerging through the metrics work, it appears that ABC, as conventionally understood, is not well suited to aid decisions concerning A3 agility.

Traditionally, ABC has been used to take an existing, stable enterprise which is well understood (or understandable) and decompose the costs in a more meaningful way than common accounting methods allow. The result can then be used as a *costing* method to derive the costs of existing products and minor variations on them. More advanced use of the technique can allocate time, risk, opportunity and other measures under the more general rubric of *Activity Based Management* (ABM).

ABM shares at least one major philosophical point with agility: the emphasis on the activity (or process) rather than on a functional breakdown of the enterprise. The latter is an artifact of a paradigm quickly becoming obsolete. The commonality of this perspective may be what has erroneously brought the ABM and agility communities together. Some ABM-related practitioners use a *transaction analysis* paradigm that is very close to what is used in the AVE project. But there are problems.

Part 2, Agility Issues

ABM depends on the ability to extrapolate information about change from existing accounting-like data. At the simplest level this fails in the case of situations which benefit the most from agility, those which experience radical change. And there is a fundamental reason for this: ABM extracts its numbers before the analyses are performed. The original causes and relationships that the numbers represent must *stay still* in a sense.

There is no dynamism in these numbers; the metrics are downstream in the sense that has been discussed. Moreover, they are *retrospective*. Both of these mean the same thing in the agile context. The measures can be used to help understand what has happened, but cannot be used to predict the results of the activities in new circumstances.

An upstream agility metric must allow the analysis to be performed on the cogent relationships themselves to produce numbers which are of the cost and time type.

It has been noted that there are other problems as well, though these are secondary in some sense, since the above noted inadequacy is fatal; ABM depends on accounting-like measures as its atomic unit. It derives costs from costs as it were. But it is very difficult atomically to derive costs from implicit, intangible, tacit activities in the cultural and social infrastructures. Likewise, it is difficult to accommodate non-deterministic phenomenon in the arithmetic functions which form the basis of ABM.

But the cultural/social infrastructure is one of the essential components in making agility and the VE work. The ability to characterize it in an upstream way (understanding the processes) is essential, but is, for structural reasons, outside of the capability of ABM.

Because atomic transactions are captured as numbers, losing functional content, ABM methods are particularly ill suited for understanding agility in the information infrastructure. The net result is that ABM is one of those methods which appear to be useful for helping one's enterprise be faster and cheaper, and probably better, but it cannot help with making it more agile.

ABC could support agility. Notwithstanding the structural differences, it appears that ABC could end up being a rule-of-thumb tactic in supporting certain scopes of agility. For example, one of the features which we measure is the difference between how transaction process boundaries are handled. If the VE type is 3 (Supplier Chain) and the infrastructure issue under consideration is business processes, then how reward (meaning costs in this context) is measured means a great deal.

If two processes, one in the prime and one in the supplier, both figure their reward structure the same way, and if the granularity is higher, then the agility will be higher. This is not a result of ABC per se; at least, it is not the need for which it was created. Instead, it is a result of ABC being the same on both sides (as well as being consistent and being *true*).

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13.5 Lean Manufacturing

[Lean and agile manufacturing are siblings, but being one doesn't necessarily result in the other.]

Other agility workers have proposed that *Lean* Manufacturing and *Agile* Manufacturing are cut from the same cloth. But that does not appear to be the case. The Chrysler example is just one example and we've found extensive confirmation in industry.

Lean focuses on profitability *today*. Therefore, it works to lower costs, and possibly to reduce time of current product portfolios. Improving quality does not appear to be an intrinsic result of lean, but a result of concurrent adoption of complementary quality initiatives.

Agile focuses on profitability *tomorrow*, with the realization that tomorrow becomes today all too soon. So it focuses on the ability to change to improve cost, time, and quality.

Lean is *static*, Agility *dynamic*. Our Best Agile Practice study discovered many cases where lean and agile decisions were contradictory. By making the operation lean, often the agility seed corn is eaten.

A high value area is the overlap between the two. For example, many observers believe that flat organizational structures serve both philosophies. (It appears to be true that flatness is an agile strategy in many contexts.)

This is interesting because there appear to be some agile moves an organization will make which will cost money (or involve some other kind of compromise), and some will be *free*, a by-product of invoking some more near-term oriented best management practice.

The real value of the metrics will be in understanding the costs and benefits of agile decisions that are not freebies. This may in many instances involve making a business case for deviating from lean decisions in the direction of agile decisions.

In making this analysis, we've used the following understanding of lean:

- in the physical and workflow area (Physical Infrastructure), Lean means *JIT* (just in time)
- in the business practices area (Legal/Regulatory Infrastructure), Lean means *flat organizations*
- in the cultural area (Cultural/Social Infrastructure), Lean means ***empowered, motivated workforce***
- in the information area (Information Infrastructure), Lean means ***client-server models and standard representations***.

One difference between lean and agile is how they originated. Lean resulted from a focused survey of what was the apparent discriminator for extraordinarily successful enterprises (in the automobile sector). The term lean fits some of the practices intuitively (just-in-time workflows, flat organizations, and a decreased supplier base) and came to be applied to others as well (Total Quality Management, empowered workforce, and a focus on customer needs).

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As a result of this origin, lean practices do not derive from any underlying philosophy, and they involve known methods and support technologies. Agility is quite different. It originated from an intensive, several-month workshop of business executives who were concerned with a specific need that they knew to be of immense importance to survival, for which they lacked existing methods and underlying technology. So, by definition, agility goes beyond current knowledge. Unlike lean, all agile methods result from a common underlying vision--namely, the ability to thrive when faced with change.

Each community has claimed the other as a subset, but we believe that agility has the stronger claim as being more evolved. Certainly, a complex relationship exists between the two:

A compelling argument can be made (and it has) that agile is a logical evolution of lean. It can also be argued that, in many dimensions, lean and agile are contradictory; several clear examples are available. Yet a third proposal is that each is equally apt and modern, but they address quite different needs. Lean optimizes processes; agile optimizes the ability to adapt processes to new conditions. This view emphasizes the reinforcing similarities between the two.

This issue has no effect on the metrics. We believe all three views have some merit. Often, the difference boils down to *religious* preferences, or, more reasonably, strategic goals of the enterprise. Equally often, the views depend upon the communities of interest.

We've come to believe that some sectors are understandably less concerned with agility than others. This makes sense, because some sectors are currently more stable than others. The commercial aircraft and automotive sectors, for instance, have a very large dependent constituency (airlines, auto repair, and, in both cases, travelers). Their product models take a long time to develop and, once ready, are replicated many times. New models are always evolutionary in almost every respect.

Sectors more likely to recognize agility as important include the defense missile community, entertainment, certain vertical markets for computers, and all software. So while lean is of interest to many sectors, agility is of interest to a smaller set. But in those cases, it is *more* likely to be important.

13.6 Flexible Manufacturing

[Flexible manufacturing is an (uninteresting) special case of agility.]

The difference between *agile* manufacturing and *flexible* manufacturing is more straightforward. Flexible is a subset of agile. In particular, flexibility is agility limited to the physical infrastructure.

When we're talking about flexible cells, processes, warehouses and even relationships, we generally mean to focus on the capital investment. Unfortunately, many of the examples of agility which have appeared are of *physical* agility, so cannot be differentiated from flexibility, which is not very revolutionary or even new.

Those examples do not constitute interesting situations so far as the metrics are concerned.

13.7 Electronic Commerce

[Electronic Commerce and agility are largely unrelated.]

Substantial excitement, and consequent investment in development, has focused on Electronic Commerce (EC). Some of this work has been called agile. Our position is that essentially any business relationship can be termed a VE. We've tried to capture the difference between interesting and uninteresting VEs. The differentiator between interesting novel VEs (Types 1 and 2) and relatively uninteresting ones (3 and 4) is that the former use new, novel, fundamentally different types of business relationships.

If all EC does is lower the cost or time of conducting business in conventional ways, for example advertising and ordering via internet, then the order of agility that can be accommodated is low. In order to be interesting, party A should be open to, for instance, having party B's supervisors, equipment, workers, equipment or processes intermingled with their own in some creative way so that the VE, in that area, resembles a non-virtual enterprise, a single corporation.

In other words, most other work in the manufacturing enterprise considers the *token* being passed between entities in the enterprise being based on product information. The metrics project takes a different view. Since the focus is primarily on the *formation* of the VE, the product is the VE *infrastructure* itself. The focus is on how *processes* integrate, the dynamics of which are somewhat independent of the product data flow. What is sought are similar *tokens* in the form of process metrics.

There is a similar difference in paradigms between EC and the AVE. Commerce's token of exchange is the monetary unit (dollars), and EC continues that paradigm.

The VE explicitly includes the customer, but it is assumed that the partnership is more intimate (potentially) than a conventional buyer/seller one. As a working definition, the VE deals with integration of processes, even across buyer/seller boundaries (and supplier-chain boundaries). Most EC efforts *reinforce* walls at those boundaries by making them operate faster and cheaper.

13.8 Product Data, NIIIP

[Agility depends on process coordination in a way not affected by the benefits of improved product data exchange.]

Much work in the manufacturing enterprise considers the token being passed between entities in the enterprise as based on product information. This is a natural perspective in some sectors, especially the aerospace and automotive industries. The National Industrial Information Infrastructure Program (NIIIP), as well as many others which use the product data standard STEP (STandard for the Exchange of Product Data), is based on this paradigm.

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The metrics project takes a different view. Since the focus is primarily on the formation of the VE, the product is the VE infrastructure itself, not a device which can be modeled as a three-dimensional item. The focus is on how *processes* integrate, the dynamics of which are somewhat independent of the product data flow. What is sought are similar *tokens* in the form of process metrics.

This is to say that the focus is on process integration, not product integration. The technical issues involved are much more difficult and less amenable to standards.

However, there may be some lessons to be learned from the product data paradigm. Initiatives using that paradigm have encountered immense technical difficulties resulting from the choice of gracefully growing from an archaic token type, the engineering drawing. Instead of easing adoption as originally hoped, the product data standard is fighting battles for adoption not originally anticipated. A lesson may be circumspectly to reconsider assumptions implicitly carried over from legacy methods.

We stated earlier that engineering agility into an organization is a radical new idea. It would be crippled by unnecessarily carrying over obsolete concepts as a legacy.

Elsewhere, we argue that the general concept of international standards is as much an impediment to agility as it can be, in cases, a benefit. Consider the situation where two persons need to collaborate.

If what you want is a high level of plug and play among persons and a high degree of refinement in the process, standards are useful. For instance, artillery crews are trained to use a standard, concise subset of English in communicating; a specific small glossary is used. The standard is in the token that is passed.

The resulting system is very agile in the sense of being able to substitute participants. But it is unagile when the situation is highly unpredictable. So Special Operations Forces (SEALS, Green Berets), for example, are not restricted in what they can say, but instead are trained in communication skills. The medium is full-blown English. When someone doesn't understand what's being said, they fall back on clarifying or defining new terms on the fly. Much more agile.

We know of an analogy in the product data world. One supplier chain is being built that specifically eschews STEP, intentionally targeting abilities that adherence to STEP makes more difficult by making other enterprises less agile.

13.9 Enterprise Integration

[Conventional integration strategies depend on stability, not temporal dynamism.]

The Suppliers' Working Group (SWG) made an investment in studying agility and used the rubric *Enterprise Integration*. By this, we meant the information strategies required to quickly and cheaply integrate diverse components into a functioning enterprise, as in an AVE. Since then, the term Enterprise Integration has been promoted to mean something quite different, something much less challenging.

Part 2, Agility Issues

Now it means the ability to create an enterprise-wide model. A robust research, conference and standards community has appeared to support this work. Desirable as this may be, it still assumes a central point of management and a static enterprise. It's not the problem we address.

We now call our problem that of model federation.

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Part 2, Agility Issues

14 The Agile Manufacturing Research Program

[The 39 sponsored agility programs are related to the Reference Model.]

Elsewhere we describe the substantial effort of the Agile Virtual Enterprise Focus Group and its primary product, the AVE Reference Model. That model has proven to be quite useful in a variety of contexts. Specifically, it supports the work of the metrics as described here, it provided a framework to categorize the Best Agile Practices study, a recent study of agility attributes, and a mapping to the agility enablers of the Agility Forum.

We believe that the AVE Reference Model *cuts things at the joints*; it's a clean way of looking at the domain. It's no accident that things worked out well, since from the first the group decided to have a consistent focus on the process. In particular:

- we stayed true to a pure definition of agility, *the ability to respond well to unexpected change*
- we looked at a new and novel business function, the *ability to engineer appropriate levels of different types of agility into an enterprise*
- While keeping that focus sharp, we deliberately broadened the view of the business model. While including conventional integrated enterprises and supply chains, we also addressed not-yet-seen, advanced models of the Virtual Enterprise. The model was intended to be generic in this way,
- We stuck to process breakdowns, where a process was activity which required resources and involved a decision. This differs from functional breakdowns which emphasize roles (marketing, manufacturing) not behavior.
- We worked hard to separate the infrastructures, because we knew that different laws would be at work.

As a result, the Reference Model is a robust way to view at once the spectrum of activities in the AVE which is presumed to be the superset of all for-profit business activities. One use we've put the Reference Model to is understanding some of the other sponsored agility projects. There are a large number of these.

Of these projects, none deal with the last lifecycle step, *graceful resolution or reconfiguration*. None, except ours, deals with the first step, Opportunity Identification. Only one, the work of Work and Technology Institute deals with the importance of *Social and Cultural Infrastructure*. Our project, and those of Intelligent Systems Technology and Knowledge Based Systems are the only ones that deal with information infrastructure, which in our model is purely the modeling, abstraction and representation strategy.

We believe our project to be the only one focused on A3 Agility, the directly engineered ability to adapt well to unplanned change.

The following tables show the full Reference Model and the subset of the model's cells addressed by the projects..)

	Social/Cultural: Human Dynamics	Social/Cultural: Community Cultures	Social/Cultural: Business Cultures	Legal/Explicit: Business Processes	Legal/Explicit: Contracts/regulations	Legal/Explicit: Workflow	Physical: Logistics/Warehousing	Physical: Equipment	Physical: Laws of Physics
1. Opportunity ID									
2. Partner ID									
3. VE Formation									
4. VE Operation									
5. Reconfig/Dissolve									

Table 14-1: Full Model and the Cells of Interest

	C. Legal/Explicit Infrastructure	D. Physical Infrastructure
2: Partner ID	1-15, 24, 30 22 20	22 20
3: VE Formation	1-15, 24, 30 20	31, 32 20
4: VE Operation	1-15, 24, 30 16-19, 21, 23, 25-29, 36-39	16-19, 21, 23, 25-29, 36-39 31, 32

Table 14-2: Projects Mapped to Subset of Reference Model

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- Row 2: Partner Identification
- Row 3: Formation
- Row 4: Operation
- Columns C: Legal/Explicit Infrastructure incorporating legal, business process and workflow issues
- Columns D: Physical Infrastructure incorporating warehousing/logistics, and equipment and

The related, sponsored research projects, are:

- 1. Agile Infrastructure for Manufacturing Systems
- 2. Agile Manufacturing Development of Castings
- 3. Agile Manufacturing Decision Support Systems
- 4. Chemical Management Information System
- 5. Codifying Knowledge about Agile Business Practices
- 6. Decision Support System for the Management of Agile Supply Chains
- 7. Enabling Next Generation Mechanical Design
- 8. Enterprise C3I Decision Support System
- 9. Hierarchical Enterprise Decision Support
- 10. Integrated Process Planning/Production System
- 11. Large Scale Simulation and Resource Scheduling Based on Autonomous Agents
- 12. Process Tools for Virtual Enterprise Management
- 13. Process-WEB: Process-enabled Planning and Composition of an Agile Virtual Enterprise
- 14. TierII+ AGILE Support Concept
- 15. Virtual Enterprise Engineering Environment
- 16. Activity Based Costing for Agile Manufacturing Control
- 17. Agile Web Pilot Program
- 18. Labor Infrastructure for High Performance Transformations
- 19. Manufacturing Assembly Pilot Project
- 20. Metrics for the Agile Virtual Enterprise (This Project)
- 21. Migration Strategies for an Agile Logistics Infrastructure
- 22. Qualification Criteria for Agile Enterprises
- 23. Supply Chain Integrated Product and Process Design
- 24. Strategic Planning and Operating Tools for Agile Enterprises
- 25. Agile Textile/Apparel Initiative
- 26. Fast and Flexible Communication in the Aerospace Industry
- 27. Fast and Flexible Communication in the Automotive Industry
- 28. Nationwide Electronics Industry Sector Pilot

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- ♦29. Advanced Collaborative Open Resource Network
- ♦30. Agile Manufacturing Information Infrastructure
- ♦31. CAMnet Prototype and Wrapper Tools
- ♦32. PartNet: An Infrastructure for Product Information Distribution and Electronic Commerce
- ♦33. Aerospace Agile Manufacturing Research Center
- ♦34. Machine Tool Agile Manufacturing Research Center
- ♦35. Electronics Agile Manufacturing Research Center
- ♦36. MEREOS
- ♦37. National Industrial Information Infrastructure Protocols
- ♦38. National Industrial Information Infrastructure Protocols Lite
- ♦39. Cooperative Network for Dual-Use Information Technology

The projects clump into the following cells:

- ♦Spanning C.2, C.3 and C.4: are projects 1 through 15, 24 and 30
- ♦Spanning C.2 and D.2 is project 22
- ♦Spanning C.4 and D.4 are projects 16 through 19, 21, 23, 25 through 29 and 36 through 39
- ♦Spanning D.3 and D.4 are projects 31 and 32
- ♦(Projects 33 through 35 are diverse and are not categorized)
- ♦Our project, number 20, covers Columns C and D in rows 1, 2 and 3.

Part 2, Agility Issues

15 Summary of the Method

[Given the above constraints, a short statement of the approach is given.]

We focus on analyzing processes to evaluate their agility, their ability to *adapt*. We provide a method to do so, and indicate associated methods which are required to support certain needs.

What goes *into* this evaluation are models of ordinary processes within an enterprise or across partners. What comes *out* are numbers or functions which indicate the time and cost of change. Either a pair of processes are compared (resulting in the time and cost of changing from one to the other), or a single process and an agility scope (resulting in a time and cost measure of the intrinsic ability to change in certain ways of the process).

The bad news is that the metrics can only be applied where process models exist. Where processes are not modeled, the models must be created. Where explicit models are difficult to capture, as in many important social interactions, the behavior must in some way be captured.

The good news is that essentially any modeling method can be accommodated, so planners and managers can incorporate agility considerations in models and tools created for other purposes. Moreover, an agility analysis only requires models of a few key processes in the organization, so incomplete existing models can be relatively cheaply supplemented in order to add agility considerations.

Concerning social and cultural change, we have an approach, representing new formal methods developed under our effort, which can be used to characterize sufficiently explicitly behavior whose causal processes are unknown.

The process we follow is simple at a high level. We start with models, the collected models of various processes, which incidentally can be modeled by diverse methods. And we end up with models; metrics in the formal view that we take are *parametric models*. The method we develop is a transformation of the input model into the output.

We do this in large measure by constraining the input model in three steps. The three filters we use are intuitively describable:

- Constrain to Infrastructure Breakdown. Here we force the process decomposition to fall into a standard parsing of the Virtual Enterprise (VE). This normalizes the input models and directs the focus to the creation and change of infrastructure, the core phenomena of interest.

  The work we have done in this effort is novel, and it results in rigorous definitions of agility. It could have been done by others. There could be some mild controversy here concerning our focused use of terms that others may use in more loose ways.

- Constrain to Communicative Acts. This forces the representations into a standard form that sets up the next step. It results in a normal form that directly relates interaction with tools by others, by agent-based approaches, and by repositories of cases and agile processes.

  This work is borrowed wholesale from others and rests on well established, non-

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controversial foundations.

- Constrain to *Agility Features*. This third filter is the most novel; it extracts five complexity measures from the processes that pertain to agility. It employs some novel mathematics in its most complex form, as an input to strategic planning/ simulation systems. But we have also developed a simple arithmetic method for common situations that requires no special skills or automation support.

This work in its complex form is based on unique and proprietary work.

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16 Limits of Our Approach

[The approach has limits. Here they are.]

16.1 Modeling for Utility

[The modeling approach is geared to producing the numbers as the useful result. The interim models are not generally useful.]

The approach that the project has taken depends heavily on modeling science; much of the attention has been oriented toward understanding the nature of the modeling approach and the resulting parametric model, the time and cost metric. What goes into the Reference Model is, by design, intuitive and simple. What comes out of the model, the time and cost information, is also by design very simple.

Constraining the design of the approach this way has the result that the *black box* of the features model is somewhat complex and non-intuitive. The term *modeling* is often used in the enterprise explicitly to capture and display processes and/or relationships. Often, the value of the process is in making things explicit and displaying the results so that relatively non-technical users can see what is going on.

In other words, usually, the priority is in making the *graphic display* of the model clear, which takes priority over the computability or formal utility of the model. We have opposite priorities: essentially no effort is going into visualization of the features at this point, and everything into making them computable. The model is essentially a black box so far as the user is concerned.

In part, we make up for the need for visualization by presuming a precursor model. A user will model their organization using techniques that are already in use for other management needs; most of the time, this will have already been done. The understanding of the processes from visualization is presumed to be provided by this precursor model, since we believe that the nature of agility is so different that it won't, by itself, be apparent.

16.2 Necessity for Strategic Modeling

[No strategy, no metrics. A surprising number of enterprises have no clear strategy. Strategies are expensive.]

The original intent of the project was to pursue two uses simultaneously, tactical and strategic. *Strategic* users would evaluate many options and a very large number of features to structure many elements of the enterprise. For example, a prime contractor would develop a strategy which accounted for agility, advising on the design of the supply chain: what gets bought and what factors govern.

The result would include what agility features are of interest; what the relative weighting of those features would be, and the degree of agility desired in each of those features.

The *tactical* user is an empowered decisionmaker working later in the life cycle, and implementing the strategy. For instance, a middle manager may be evaluating

which of several suppliers support the enterprise's agility goals. This manager deals with a much simpler case than the strategic one; there are simply fewer variables.

But there is a more fundamental difference in that the tactical manager is presumed to have the guidance, the agility requirements, set by the agility strategy. It appears that we cannot use the metrics in any meaningful way tactically without such a strategy.

This is another limit of the approach, at least tactically, and is a result of the unavoidable truth that *all agility is strategic at root.*

16.3 Second-Order Agility

[This version measures the ability to change, not the ability to change your ability to change. That's for the future.]

In the course of the work, we went back to many of our best practice examples to evaluate whether the metrics would have been directly useful. We were surprised to find many cases of second-order agility which were not captured in the original approach.

Second-order agility is a result of those actions that do not directly follow from the existing state of the enterprise. A second-order effect would appear if an early response to a change fundamentally changes the enterprise's ability to respond. For example, consider the simple case of physical agility in equipment and the simple dimension of increased capability. A first-order measure would consider the ability to increase the output of the existing equipment.

But what if the supplier has an outstanding order for new equipment which they accelerate as a result of the new demand. This is meaningful agility that is not apparent from examining the capability of the existing physical system alone. But this capability, the ability to order and quickly incorporate new equipment, can be captured if at the system level.

The lesson is that the knowledge that is captured must include features from a system-wide perspective. Our initial belief that local analysis would have some incremental benefit was false; in order to get any appreciable value, the features need to be evaluated system-wide.

The resulting constraint is that the metrics are not incrementally implementable. In fact, since the social and cultural factors have been excluded from the first phase of the work, the interim metrics are incapable of fully exploiting second-order agility. This limit on the approach also results from the fact that *agility is essentially a strategic, system-wide set of capabilities, not a state.*

16.4 Possible Lack of Quantitative Information

[Suppliers will have scant idea of the questions you'll be asking. There are additional costs associated with education, with obvious side benefits.]

In future work, we intend to develop a modeling technique to insure the correctness and completeness of the knowledge capture process. But, until then, we have to depend on existing modeling techniques, under the assumption that enterprises will want to use information that is already captured, or to use methods with which they are familiar.

We need information that is captured in quantitative form, together with all of the relevant causal relationships. Both characteristics, being *quantitative* and including *causality* are desirable for the integrity of the approach. But we find that such information rarely exists in cheaply accessible forms, much more rarely than we initially thought.

Most quantitative information suffers from the accountant's syndrome: effects are measured, usually in the form of time and cost, but the complex causal relationships that a robust model would capture are lacking.

Another problem is the nature of the existing models where some dynamics and inter-relationships are captured. Models fall into one of three types: *descriptive*, *qualitative*, and *quantitative*. The first type are the most common and the least useful for our purposes. Usually, they just display relationships as an aid to help managers think more deeply than they otherwise would.

Our site visits revealed very little in the way of existing quantitative information, which means that the information collection process could be more expensive than originally thought. The good news is that the approach overall is tolerant of the type of input. One cannot get high integrity quantitative information out even if only descriptive information is fed in. But some coarse analysis can be done with notional, descriptive information so that one can determine where more apt information gathering is profitable. Therefore, this limit of the process is not so severe.

16.5 Agility and Evolution

[Becoming agile may require a more serious commitment to reinvention than most firms are willing to make.]

The final limit on agility is perhaps the most basic. The concept of engineering agility is a radical idea which is already eminently useful in many sectors. But its radical nature can be a disadvantage as well. Agility is a simple concept to understand in theory, but conceptually it can be difficult to apply to specific cases. Four years of work by the Agility Forum has underscored this difficulty.

The actual identification of agile needs or behavior in a specific application is the only major step that has thus far eluded us in pinning down a rigorous, comprehensive definition. Identifying such needs appears to rely on some *art* in the eye of the analyst as well as some fearlessness in abstraction.

For example, according to the way we describe it, the whaling industry was agile, with some of its core competencies surviving to the present day and forming the basis of our largest contributor to balance of payments (movie-making). But all that would be scant comfort to the by-passed candlemaking enterprises, to whom the whole affair appeared quite brittle. In the SEMATECH example, the idea that

the manufacturing goal was in the fab and not in the chip could not be adhered to even after initially adopted by the sponsoring group.

We offer the following insight: some problems in identifying agility behavior or needs boil down to insecurity about whether agility is a tool to *maintain* an accustomed *evolution* (in effect, the status quo), or to *enable* a directed *revolution*.

If an automobile company looked at agility as a technique merely to improve its competitiveness without fundamentally re-examining itself and what it does, it may have trouble coming to terms with what agility is. It will most likely see agility as much like other productivity/profit maximizing techniques, such as those collected under the rubric of lean.

If, on the other hand, an industry is undergoing revolution, and a company is looking for a way to continually reinvent itself, to change in order to take advantage of change, then agility is easily applied. The questions then become less intransigent, and the needs are more apparent. We believe that the aerospace defense community is unavoidably in such a revolution, and so is an apt candidate for agility.

The U. S. automotive industry (including workers, industry suppliers, and the follow-on repair market) is instead in the mode of working to preserve large, stable institutions and practices with a minimum of change, so will likely perceive agility in a more limited way.

It's a question of whether we merely react or we intentionally build an ability to adapt. We, of course, are promoting the latter. The underlying issue is whether the cost of much evolutionary change is actually less in real terms than the cost of possibly-small changes based on revolutionary analysis. Each enterprise must make that evaluation for itself in considering engineering of agility.

Part 3, Soft Modeling

[Part 3 is for the reader who is interested in social and cultural issues and what we've done about them. Many examples are in this part.]

17 Abstract

We begin this part by recounting an extensive example beginning in the whaling industry and ending with agile movie production processes. We continue with a specific movie case, software coding, Russian entrepreneurs, and virtual car manufacturing.

Cultural agents are introduced, and some background issues discussed. Trust, trust agents and trust metrics are defined.

We review French and English history to extract key insights into defense engineering practices. Then we tie it back to the movie example with a case of trusted agents using lightweight contracts and unifying themes. And the whole affair is further tied back to the defense case. The case for defense support is made.

We then turn to the specific approaches to soft mathematics. Situation theory is introduced and explained.

We report on our activity in setting up a workshop, report results of that workshop, and detail future action that we plan.

Part 3, Soft Modeling

18 An Historic Case

[The primary focus of this section is the thread of case studies revolving around the movie production business.]

Much of the principle investigator's career has been devoted to helping shape U.S. Department of Defense investments for the domestic industrial fabric. Befuddled by contrasting speculations on best strategies, he searched for some hard data derived from similar prior situations. What he found surprised him in terms both of the successes and the failures--and convinced him that historical cases can be helpful for understanding the virtual enterprise and the government's role in providing for them supporting technology.

18.1 Military Research "Can" Do's and Don'ts

[Defense research flubbed up on the can opener. Why?]

Military research has influenced daily life to a much greater extent than most of us realize. For example, the British military sponsored the development of the now-ubiquitous *tin can* in 1810. This innovation brought to critical mass forces which revolutionized agriculture, since food could be distributed like a manufactured good. The military's concern was the long range projection of supportable military power, and this one advance played a consequential role in the expansion of the British Empire.

What is surprising is that the *can opener* was not invented for nearly another half-century. It ultimately appeared as the result of a small U.S. Army research project, and the new can openers played a role in the early days of the U.S. Civil War, since the South lacked them. In the intervening years, cans were presumed to be opened by whatever was handy: knives, chisels, or even shovels and bayonets. It has been reasonably speculated that during this fifty years time more military casualties resulted from opening cans than from combat.

Why did it take so long to invent what we now consider such an obvious device? It was not the lack of a well-funded military research effort. In fact, substantial amounts were spent by the military on can research. But the requirements for the cans came from the planners, not the users--so the efforts focused mostly on the optimum size and shape of cans for the variety of logistical packing situations encountered.

We found many cases where even the most (retrospectively) obvious innovations eluded the research establishment. Several lessons here helped us immensely; one of these was the confirmation of the value of historical study.

18.2 Show Me

[The study begins with an interest in legal agreements for movies.]

In 1994, the Agility Forum decided to review Best Agile Practices in businesses today. The study was intended to move the vision and practice of agility a giant step forward. Sirius-Beta was tapped to lead the virtual enterprise effort. The Agile Virtual Enterprise Focus Group directed the work, both in the agenda and in some of the enterprises to survey.

In terms of the agenda, the Group was faced with a conundrum: the only enterprises we could survey were existing ones working on current problems. But the only way to test these for agility would be to look back from the future to see if they had responded well to change. Some felt we should have been sent out to look at historic examples.

The first industry we were directed to look at was the *movie production business*. It is a living enterprise, which manifests itself in very high value, short-lived partnerships, varying greatly from situation to situation. It is a highly successful industry, providing a significant source of foreign trade, bested only by commercial airliners. And its role in technology development is growing.

Duly following the direction of the group, we consulted a knowledgeable insider and was exposed to a remarkable collection of virtual enterprise practices in movie production. The bad news: in several interesting cases, we were unable to overcome proprietary wraps on competitive techniques, so the case was not reported. The good news was that our contact possessed some rare knowledge; he knew how one of the movie industry's best practices evolved.

The movie business relies on a contract tradition that keeps legal instruments very lean, relying on a near-Talmudically comprehensive, but implicit set of ethical principles. Underlying that is a large body of case law governing the virtual enterprise. Together, they provide a sufficiently robust adjudication mechanism that the partnerships can be made quickly and cheaply. Remember when Kim Bassinger was bankrupted for reneging on a simple, verbal statement that she would do a picture?

This case law and partnering tradition can easily be traced to the early oil exploration business, according to our enlightened informant. Los Angeles in its pre-movie days was an oil boom town, and the movie people adopted the existing local legal infrastructure. These legal practices originated in the home of oil exploration, Pennsylvania, which in turn *inherited* them from the previous oil industry, namely, the whaling business.

Finally! An important historical case. Now we could test agility in a longer time frame and simultaneously satisfy my penchant for examples outside of our current buzzword analyses. What we found greatly expanded our understanding of how an agile virtual enterprise could work.

18.3 The Whale of Fortune

[The U. S. dominates the important world whaling industry.]

We discovered that the use of whale oil had profound effects on our culture. The candles made from it were much brighter and relatively smokeless compared to the tallow candles which had been the standard. This superior lighting afforded people a much wider range of nocturnal activity; government and business were better able to function at night; public performances of all sorts could now be held after dark.

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Whale oil also altered our society's relationship with time. The fine lubricating oil found in the head of the sperm whale allowed for the advancement of mass-produced precision machining. The pocket watch became the first technology product for the masses. It is hard to overestimate the impact a scheduled day has had on the way we structure our lives and businesses.

As one would expect, there was a great demand for such revolutionary products, which translated into an enormous amount of wealth for those who could meet it. With an economic multiplier effect comparable to that of the semiconductor today, whale oil enabled the production of goods which could be sold for a thousand times the cost of collecting the oil used to make them.

For several decades, first from Nantucket and then primarily from the nearby New England town, New Bedford, the expeditions were launched and received which supplied 90% of the whale oil used in the world. This tight grip on such a lucrative market meant that whale oil played a more important role in maintaining a favorable balance of trade for the U.S. than any other product, even tobacco or cotton.

The whales from which the oil was extracted were hunted mainly in the Pacific and Indian Oceans. How was it that such a crucial industry stayed almost exclusively centered in two small towns located so far from the point of extraction?

18.4 Virtual Whaler Dealers

[A whaling party was a virtual enterprise.]

We found that geographical and professional isolation allowed for the evolution of a unique and very effective system: a system which for many years put a brand new, fairly high risk/high payoff, virtual enterprise (VE) in the water at the rate of one every two weeks. Here's how it operated.

The return of each whaling expedition triggered the formation of another. It was considered an invitation to bad luck to reuse the same combination of partners, so during the six to nine months it took to recondition the ship for another voyage, the owner of the boat assembled a new group of key players who would join him in setting up the basic physical and social conditions needed for a successful venture.

The primary partners required to launch a voyage consisted of a ship owner, an insurer (of the ship and cargo), a provisioning financier to supply the expedition with food and other consumables, a captain, and often a manufacturer who agreed to buy the oil at a set price. This component of the partnership was formed in the first couple of months, the partners being determined partially by availability.

Just a month or less before the ship was ready to sail, a secondary group of partners, the crew, was formed. They shared a distinct *cultural* background; almost none of them had, or would ever, serve in the Navy or the Merchant Marine. This professional distinctiveness, coupled with an intense *geographical* concentration, fostered the development of a unique culture based on the VE.

Every voyage included a team of skilled craftsmen--carpenter, blacksmith, cooper (barrelmaker), and a sailmaker (often a boatwright, a rigger, and even a cook were also in this class)--whose combined expertise allowed the enterprise to respond effectively to a broad range of situations. Each of these professionals, along with the tools, supplies, and sometimes apprentices they brought aboard, formed an essentially self-contained *business* which was integrated into the enterprise as a whole. In these cases, it was not just the person who signed, but their *business*.

From the shipowner to the cook, everyone was paid with a pre-arranged percentage of the take. The size of the shares varied widely, depending on what value one was expected to add to the venture, and was negotiated at signing. (Ishmael, the narrator in *Moby Dick*, signed up as a deck hand for 1/300th of the profit. Ishmael's companion, Queequeg, who was almost turned away by the shipowner as a pagan, was ultimately offered a substantiality larger sum than his friend after he demonstrated remarkable skill with a harpoon.)

As in the current movie industry, the contracts which formalized these partnerships were very lightweight (usually, for the whaling crew, just a small chit, often marked with the illiterate's *X*, containing the person's name, occupation, voyage and share), but were supported by a well-developed, culturally-based code of interpretive ethics. This code of ethics was also reflected in a large body of case law (managed by the court in Boston) as the whalers sought interpretations for the wide variety of unexpected situations they encountered.

Shaped by precedent, this case law grew sufficiently robust to support the lightweight legal agreements of the VEs which together comprised an immense industry. This case law governs the virtual enterprise today--the same kind of infrastructure used by our contact in the movie business to support speedy but robust lightweight contracts.

The constant reconfiguration of the same people, from the same place, into different small groups created a situation where everybody knew everybody. Word quickly passed that one particular blacksmith was an incompetent loafer, or that another could do the work of two men in half the time. An organizing entity had access to a potential partner's reputation, which had been established by the observations of hundreds of peers who had worked closely with him. This capability--a service that might be provided by tomorrow's reinvented unions--had the effect of keeping the quality of the teams high. The rapid turnover (each voyage took about two to four years) also hastened the evolution and universal adoption of best whaling practices.

18.5 The Guild

[Captains were the owners of persistent knowledge, culturally bounded.]

The tradition of learning from combined experience was especially apparent in the relationship among captains. They were the *process planners*; they knew what had to be done and in what order. Their combined body of knowledge was continuously expanded and refined through rigorous professional collaboration, which was institutionalized by each in the form of the captain's log.

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It was a primary part of every captain's job to take detailed notes each time a whale was sighted and to record when and where they were absent. A specialized shorthand evolved; for instance, they marked, with specialized stamps, the type and approximate size of the whale. They wrote down the direction in which the whale was going, at what longitude and latitude it was seen, at what time of day, the weather, any notable antecedents, and even the disposition the whale. In this way, they provided documentation for significant process innovations afforded by a combined analysis of all such logs during the six to nine month period of VE formation, a period of strategic planning.

The U.S. government, aware that these efforts were essential for maintaining an American lead in the whaling industry (and hence dominance of the sea), authorized the Navy to do *knowledge representation* research to help improve the quality of the captains' logs and of the subsequent analysis. This was likely the first military-industrial joint research in process modeling and planning. The Navy also invested in navigation, sea flow, animal migration, and weather prediction aids, transferring the resulting technology to the captains.

The resulting jargon, tailored for describing the pertinent details of the profession, acted as a form of security protection, as only an insider would have been able to extract the full meaning from a captain's log. The process plans were shared freely among the captains of Nantucket and New Bedford but not with outsiders. Collectively, they contained data taken from thousands of expeditions and were used to discern the migratory patterns of the desirable whales. With this information, the American captains could find the whales at any time of the year, an ability their competitors lacked.

Realizing that the captains and their collected knowledge were the reason for the U.S.õs advantage in the whaling industry, one entrepreneurial British nobleman visited Nantucket, expecting that, having seen their preferred setting, he could then build an even more favorable one in England and lure them there. This plan failed, only one of many unsuccessful attempts by the international competition.

18.6 The Gilded

[An agile response as whalers respond to the gold rush.]

Agility is often displayed as an ability to recognize and capitalize on a changing situation as an opportunity. A whaling Captain Starbuck, hearing of the Gold Rush in California, correctly assumed that success depended not on metallurgical, but on organizational skills, the same skills which the VE routinely exercised in whaling.

He led an expedition which was typical of many others. With the ability to form and transport well equipped, versatile teams to the area quickly (some ships on their way to the whales heard the news of the gold and diverted en route!) the whalers made very effective miners.

At first, while they were still able to find buyers, they sold their ships for scrap in San Francisco, and later they simply abandoned them in the bay. Testifying to the sound design of these VE partnerships, the same basic team was used for mining--except that there wasn't much use for the sailmaker. (Levi Strauss, one such sailmaker, built a business making durable pants for the miners out of the abandoned canvas and rivets.)

Complementing the suitability of the whalers as a unit, the partners themselves possessed a constitution well matched to the challenges of mining. These men were used to living the hard life; family separation, poor food, and long hours were the norm on a voyage. They were accustomed to delaying financial gratification and following orders, even while handling material of great value. Apparently, they could also limit their consumption of alcohol well enough to stay alive for the duration of the mining process, a skill lacked by many of the other miners, some of whom were successful in other regards.

18.7 Oils Well That Ends Whale

[Another agile response as the whole industry reinvents itself.]

Fortunately, for those interested in a case of agile response to *economic disaster*, the first oil well was drilled in Titusville, Pa. in 1859, right at the height of the whaling industry's golden age. Petroleum, available in great quantities, quickly became cheaper to produce than whale oil, and could be used to manufacture similar things. Each new rig in effect represented a broadside to the whaling industry. During the worst period, demand for whale oil fell about 15% a year for 7 years.

The whalers responded by drawing up new process plans and retooling--with the help of the Navy--in order to shift away from hunting sperm whales in the Tropics; they moved to the Arctic to hunt baleen whales, whose long flexible *teeth* (baleen) could be sold to manufacturers of corsets, buggy coaches, and umbrellas. The industry stayed strong for another thirty years, the whalers having effectively doubled the life-span of the most prosperous years of their trade.

18.8 Some Lessons Learned

[Culture is key. In this case, it lead to trust-enabling case law. The culture may have a self-preserving life of its own.]

The whole experience described above taught some lessons about the AVE. The Metrics project assumes that the AVE can be engineered. What we have seen in this historical research is an AVE-enabling environment, or several of them. So it is reasonable to conclude that some features which were important in this example would also be desirable to engineer into an enterprise.

Initially, the whaling industry depended on a *unique, homogenous culture*, isolated geographically (on an island, Nantucket, before it included the deeper port of New Bedford), religiously (Quaker), and professionally (not mixing with other marine cultures). But over the life of the example, many decades, this culture, with-

out adaptations, likely would have stagnated. One historian speculates that several *challenges* to the culture were instrumental in keeping it strong.

When the center of the oil industry moved to the mainland, it became separated from its Quaker heritage. Quite interesting is the subsequent assimilation of people from different national and ethnic cultures. Over time, the community became quite diverse, as other nationalities and natives from primitive locations, many from the South Pacific, and some from Africa, were assimilated. This seemed to prompt a reinforcing evolution of the culture. Was it an accident that it was the custom to change crews each voyage? Perhaps it was an instinctual move?

Much has been made of trust in agility discussions. The whaling example used a very lightweight contractual infrastructure. Clearly this was based on trust, but much of that trust seems to have been based on a confidence that the law would apply just principles to arbitrate in unknown situations. It appears that this by itself constituted a significant barrier to entry into the business by countries whose law was based on code.

The comparative cases of privateers (sanctioned pirates) among French, Spanish and English opportunists clearly shows the value of common law (or case law) as a foundation for trust in the ships. In both the English privateer and the U. S. whaling situations, a simple system of shares was made possible. Systems based on code law were fragile, since the conditions of such adventures were so unpredictable. Cheating and mistrust, and a subsequent lack of robust recourse in the justice system, were more prevalent among the privateers from countries with code law.

This common (or case) law basis of trust carries over today in the film industry, where agents inside the culture form share-based VEs predicated on ethics that are attuned to a (still developing) case law. It appears to be no accident that the centers of film activity in terms of quantity and diversity are all former British colonies--India, Hong Kong, and, of course, the U. S. French film industry executives often complain of a structural difference that stifles them, a stifling which is actually exacerbated by government subsidy (and, in this case, the greater the subsidy, the more stifling). For a more developed discussion on this issue, see A Key Difference: The Engineering Paradigm below.

It is notable that, despite substantial wealth and energy, the whaling industry never became vertically integrated up the food chain to include the manufacture of products. This lack of tight linkage allowed agility in changing the food chain from oil to baleen. And it also provided agility in allowing those manufacturers to switch to petroleum as soon as the opportunity appeared.

The linkage up the precision machining chain was also very loose. The U. S. during this period was never able to catch the Germans and Swiss, whose innovation was highly dependent on sperm whale oil lubrication. (Incidentally, that oil continued to be used until the 1970s for applications of the most demanding precision, like gyroscopes on the Apollo mission, and similar military missiles, until being replaced by the oil from the Jojoba bean.) So it seems that a loose supply chain coupling is often more agile, which is contrary to current lean thinking.

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Part 3, Soft Modeling

Finally, we looked closely at the government (mostly Navy) support of the industry. Evidently what was most useful was infrastructure research on navigation, record-keeping, map making, and on specific *high-tech* tools like telescope optics. Government research apparently failed in all the *direct* tools, like improved ship, boat, harpoon, and storage container designs. In each case, the market responded faster and better with new solutions. These bubbled up from the users, and the then-growing patent system provided meaningful incentives. It is worth noting that the deliberate exclusion of patent coverage for infrastructure elements contributed to the concurrent lack of market incentive.

Following the chain of whaling to petroleum to movies across the country could lead one to all sorts of unsupportable speculations. A smart observer of social issues has suggested a limit which she thinks has been shown in the stability of whaling's social/cultural system. She believes, as we probably all do, that there is a limit to the amount of change a social system can accommodate. But she goes further in characterizing the limit as not one of breakdown, but one where power tends to be collected in a few entities.

The effect is that social coherence is maintained by the concentration of power over the interactions in the enterprise. It is as if the system surrounding the enterprise is able to evolve in ways apparently harmful to society in order to survive. This view of organizational evolution provides another paradigm.

The example in the whaling case comes from what actually happened when the system was stressed in transitioning to petroleum. When he first encountered the oil business, J. D. Rockefeller was a clerk, a man with no recognized direct business value to add. What he apparently did add was a strong autocratic control paradigm that acted, ultimately, as an attractor for immense wealth.

The system needed this to survive, since the various social balances which had evolved over time were inadequate for the magnitude of change being experienced. So the system in effect *chose* Rockefeller's autocracy as a survival strategy. (A similar analysis, she suggests, could apply to the software industry.)

We'll return to many of these issues in this Part 3 on soft modeling of social/cultural issues in the AVE.

Part 3, Soft Modeling

19 Social Issues at Work

[More examples.]

We've had to separate out the Social/Cultural infrastructure from our initial project scope because rigorous modeling techniques don't exist. But everywhere we go, the story is the same: if we do not address social/cultural issues, the metrics will be severely limited in applicability.

Consider the following examples:

19.1 Waterworld

[One Japanese-owned studio makes a bad cultural decision.]

We've learned a lot about Agile Virtual Enterprise (AVE) dynamics and possibilities from the movie business as noted immediately above. The recent movie, *Waterworld*, presented an interesting cultural example. The movie was filmed virtually all on floating sets. Two of these sets were to be constructed from scratch, as is typical of most sets. However, there was a longer development period for this film than for most.

The production company was faced with two choices in assembling its Virtual Enterprise (VE) to supply these sets. The default choice involved using the existing pool of craftsmen who already were a normal part of the industry. These people understand the foibles and peculiarities of the business.

Sets are designed to convey a *feel* and also to accommodate the mechanics of camera placement and movement. In both cases, frequent changes to the sets are communicated verbally through the day in language which would often be unintelligible to outsiders, and some of the changes would be effected overnight. This way of working among designers, engineers, and craftspeople is unique to the industry, in the dominance of artistic effect.

The existing community lacked the engineering and safety skills necessary to deal with floating sets. To provide those skills would have required sending people to school--an option for which there was time. The alternative was to go outside of the traditional community (who shared the culture) to a company which understood the engineering and safety issues involved.

They had a firm anticipated cost to use the existing craftsmen. To this, they needed to add about $3 million for engineers' schooling, safety training, and additional insurance. The Japanese conglomerate which owned the studio vetoed this route as too expensive and directed that an outside group of marine experts be used.

So a contract went out to a well-known shipbuilding/aerospace concern to engineer and construct the sets. This company follows a model, conventional in their industry, where all the requirements are set, then the design and engineering performed, and finally the items manufactured and supported. Needless to say, there was a substantial distance between the cultures of the engineer/shipbuilder and the rest of the production's AVE. Artistic effect is an alien concept and all communication is explicitly engineering-based.

This cultural distance became an important factor. The VE presumed ad hoc flexible responses, based on an implicit group vision of artistic intent. The partner worked on a very rigid, sequential set of non-artistic processes, each one of which needed explicit documentation.

Production costs skyrocketed as many small events slowed down the process and compromised the artistic value of the end result. One such notable event was the accidental sinking of one of the sets! The estimated additional cost, over the original cost of construction, was about $80 million. As it happens, that is the amount that the Japanese management was forced to eat when unloading the production company.

We were reliably told that a metric which measures the cost of social differences certainly would have been of paramount utility in this case. Even if based on the roughest of approximations, it could have warned of the more than an order of magnitude in cost difference.

19.2 Indian Software Collectives

[Homogeneous culture is key to fast software in India.]

Here's an application with which many of us contend: *software development*. We've been dealing with a large company which develops software as a product. Often, firms such as this have to choose between make-or-buy, and one of their *buy* options has become quite interesting.

We encountered the relatively new phenomenon of *Indian software collectives*. What happens here is that a professor, usually in what we would call a junior college, trains a significant number of students in the rudiments of being programmers. Then these trainees are set up in their homes with modest PCs and are marketed to the West by the professor or a colleague.

The main value of these collectives is not that the hourly wage is cheap compared to the West, though that is the case. What matters most is that these collectives can produce relatively bug-free software in half or a third of the time of their U. S. counterparts. The reason is strength through *selective ignorance*.

In the West, a typical software development team is composed of creative individuals who have been exposed to many philosophies and controversies. It is very hard to decompose a problem and get everyone working to exactly the same script and to use the same procedures to resolve interface and common service issues. The most desired software coders are the brightest, but each of these has their own ideas that slightly color their implementations. These slight differences are the cause of both the most numerous and the most vexing bugs.

In rural India, on the other hand, each of the programmers has been exposed only to the professor's limited views. He or she decomposes the problem, and that's that. No controversies are raised because no one knows any other way, and because questioning the professor is culturally unacceptable. The resulting software therefore does not represent the most sophisticated approach, but it has the desirable quality of working seamlessly and being delivered much faster to market.

Software buyers in the U. S. are tempted in their evaluations of the potential use of these teams. On the surface, they appear to win hands down. But there are subtle questions of mapping the cultural needs of the customer to the *cultural* approach taken by the programmers. Not the least of these is the ability to anticipate future improvements and maintenance. That's most often the reason for the U. S. programmers' small differences with each other.

Subtle user-philosophy issues come into play as well, and sometimes they make the difference in customer satisfaction. There's an art to this, and a reading of customer desires, that often is lost in crossing cultures.

We've been asked if future AVE metrics which cover cultural and social issues would be able to measure cultural distances among the customers, the software publishers, and the gaggle of coders. We think they might.

20 Role of Culture as an Agent

[Agility agents, especially organizers, act in a social medium.]

We believe that introducing the idea of social factors as an agent can be helpful for characterizing social effects on agility.

For example, one of the best places in the world today for AVEs is Russia. Many, many small businesses are starting as the economy converts to free market capitalism. A large number of these are aggregating into Type 1, opportunity-driven AVEs, and some of the component companies are being created in order to fill a role in a VE. The organizer in many of these cases is the Russian mafia.

In this situation, a decidedly cultural agent plays a real role, that of VE organizer. But many of the forces at work are conventionally cultural. The mafia certifies partners and enforces an ethical law, and the mechanism for this enforcement is less a result of violence (though that happens), but because this is how people assume the process will work.

20.1 The Russian Mafia

[Some Russian enterprises are agile for surprising reasons.]

When the Suppliers' Working Group studied the most successful VEs, worldwide, it was struck by the efficiency of some large, then-Soviet, enterprises, particularly in the aerospace sector. For example, the Energia Very Heavy Launch Vehicle accomplished its goals in less than a third the time and at half cost of such a NASA project in the U. S. This was without a profit motive, a national emergency, or advanced information infrastructure. It appears that something very much like the mafia effect was at work.

Analysis by Russian social scientists traces this effect to the early days of the nuclear arms race. The Soviet nuclear scientists were in fact under a real threat of death upon failure, and often outperformed their U. S. counterparts, even adjusting for espionage.

Clearly, not all the lessons come in terms of direct transferability of a particular culture, because we cannot introduce the threat of death into the risk/reward structure of the AVE. But there is a lesson here in the potential utility of a culture-based agent.

Our case law-based movie example shows the utility of an agent. Virtually everyone has an agent in the movie business. The primary benefit of having an agent is not to handle logistics, as might be supposed. The agent is trusted with negotiating and forming the lightweight no-contract contracts we cite. The penalty for betraying trust is ostracism. Both trust and ostracism are social mechanisms.

The same dynamic is seen in a midwest-based Type 4 AVE, a bidding collective. There are essentially no external agents involved: the CEOs of these small companies speak for themselves. But the same trust/ostracism social mechanism is involved. Here, the companies are geographically proximate. But more important is a long agrarian tradition of community by shared trust. Being expelled is not just

a business action, but one that affects standing in the community. That same community establishes the fabric of ethics that governs the AVE.

The agent is the rural community itself, which shares many features of the Russian mafia.

Finally, the community as agent can even be seen in the Indian software collective. Here, there is the play of a strong class/caste system, and the membership in a higher rung of the middle class for coders. The price is in reinforcing the importance of the *academic* culture (and the role of the professor) as the organizing agent.

Social historians believe this same artificial elevation of the professor as an organizing agent for industry was a key factor in Germany's early industrial progress.

20.2 An Automotive VE

[An interesting proposal for a virtual auto plant in the U. S., now in China.]

An example of the consequences of a cultural agent can be seen closer to home. Several years ago, Sirius-Beta participated in planning for a massive VE in the automotive industry. The idea was to take advantage of all of the manufacturing processes for cars, eliminating the processes for which a large central firm were required.

The idea was to continue to remanufacture cars after they were sold. This idea extends the VE both well into the customer base and past the initial sale. In one mode, the conventional car company involved would sell a car with an additional warranty: that car would have new technology and engineering changes inserted for a specific number of years, in addition to both functional and cosmetic repairs. This would greatly increase the value of the car to the buyer and incidentally provide a robust, continuing after-sale market to the car manufacturer.

This Japanese manufacturer knew that great gains in conventional market share were unlikely and that they had already moved up the value scale to luxury cars as much as they could. But this firm--typical of several--continued to engineer autos after the first manufacture, so that the later models differ from earlier ones to a much greater extent than U. S. and German models. In the latter companies, the engineering peaks right before manufacture, and then stops, unless some safety issue is uncovered.

So why not continue to re-engineer the model for years after the sale? After all, quite a few benefits result, one of them being the extended leverage that could be obtained from the engineering data and designs for the model.

The second operating mode for the potential VE was to remanufacture autos originally manufactured and sold by others, but which had a major engineering flaw. The numbers on this are impressive. It turns out that most cars are taken off the road not for systemic, auto-wide failure--everything wearing out at once--but because of point failure in a single system.

In other words, the transmission was poorly designed and fails again and again, so the car is junked. Or a car is damaged in an accident and not repaired because

the transmission has had chronic problems. The VE would focus on the bad actors--and models were drawn up for many such cases--cars with good systems overall, but which had one point failure, a poorly engineered subsystem or component.

The VE's job would be to design a newly-engineered replacement component, and either upgrade a car retail (with the owner bringing it in) or wholesale (with the purchase of large numbers of the cars from junkyards or used car dealers).

The VE would link small engineering, manufacturing, and installation shops to do the work in a highly distributed way, along with central agents--the broker, the original engineering base, a telecommunications infrastructure supplier, and a financial agent which provided insurance to the VE and insurance and funding to the small partners.

Anyone could engineer a new part, whether working alone or taking advantage of the manufacturer's database. Such a part could be manufactured by the original designer, or the design could be advertised for licensed manufacture by others. Yet a third party could be involved for the actual installation.

We represented the government in this instance; among the reasons for doing so was the massive recovery of value in previously junked cars to the U. S. citizen. The potential was for hundreds of millions a year, the best kind of virtual tax cut. The infrastructure used for this VE could be reused, expanded into other sectors.

Obviously, this did not proceed, even though the partners were available, the money, the numbers, and the technology. What killed it was the intimidating social role that the organizing agent would have had to play. Cars play a large cultural role in American society, helping people define their identity. This dynamic is less pervasive than it was before the invasion of foreign manufacturers, but many Americans still seem to want a big company to which they can give their allegiance.

Moreover, a critical mass of the small innovators would have been drawn from a pool of *shade-tree mechanics*. The cultural issues associated with bringing these people together were considered formidable, especially so considering the location of the test case, a rural state. The Japanese decided that there was no way to manage the cultural issues; in other words, appropriate cultural metrics (including those for agility) were again lacking.

The impetus for distributed auto manufacturing shifted to China. The idea of reuse has been shelved, but the idea of manufacturing cars without a conventional prime has been retained. This VE is now to consist of a large number of small shops in China, feeding distributed, small, decentralized parallel assembly of autos for export.

The coordinating agent in this case is the Chinese People's Army, which in fact is the largest commercial entity in the country, perhaps the world. They provide significantly more value than the Russian mafia, but the idea of a culturally-based agent is still there.

The Japanese are to provide infrastructure and VE management techniques. The cultural situation is addressed in two ways. The previous heterogeneity problem of the U. S. study is erased by going to China, and by selecting locations there with

deep homogeneity. The arbitration and arranging agent's cultural skills are greatly simplified since the techniques used will include the same as those of the Soviet Mafia, namely coercion.

20.3 Defining the Culture

[Influencing the culture can incubate agents.]

The ideal agent will not only understand the cultural issues, being able to make informed decisions through metrics, but it may be able to determine certain cultural characteristics. Whether particular instances of such action are desirable is another issue. For instance, it may be desirable to have the Russian mafia in order to ease the formation of AVEs, but they are undesirable socially for other reasons.

It has long been the case that non-virtual enterprises have engineered their culture. For instance, General Electric has for decades spent large sums on understanding itself, designing where it wants to be culturally, and normalizing all its employees.

This normalization often extends to the customer base. We mentioned automobile manufacturer loyalty above. The car companies spend substantial amounts on auto racing, with the intent of attracting the kind of blind (or at least largely independent of product issues) loyalty that is given to sports teams. The idea is to determine by design some of the cultural behavior of the consumer.

Probably none have explored this territory as thoroughly as the cigarette companies. Some companies have aggressive programs to adjust the culture of the consumer, for example with *Virginia Slims*, marketed to young women. The Suppliers' Working Group concluded that these companies had the most developed models of cultural influence we could find.

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Part 3, Soft Modeling

21 Some Necessary Considerations

[Some characteristics of agile-producing culture.]

Everywhere we go, we hear the same thing: if the AVE metrics cannot handle social and cultural issues, they are severely limited. So the project developed a two-track strategy: deliver fieldable metrics which handle the explicit (that is non-cultural) issues and at the same time lay the groundwork for meaningful social/cultural issues which can use the same basic methodology. Along the way, we've discovered some constraining requirements which are outlined briefly below.

21.1 Diversity

[The strongest partnerships are those among wholly different partners.]

A common strategy in forming VEs is to *prequalify* partners, using certain criteria. Among these are:

- Does the partner share our business vision?
- Does the partner use business processes that are similar to ours?
- Does the partner share our interest in, methods for, and goals to measure delighting the customer?

All of these are various ways of asking if the partner shares our *cultural* values. We feel that these, when taken as limits, result in uninteresting VEs. The most interesting VEs, the ones that provide the most competitive advantage, are those which partner you with someone who is quite different and who offers something the VE needs. The more like you the partner is, the less likely it will complement your capabilities in a profound way, in a way that will outwit your competition.

It's not at all necessary that your partner think like you, or even that it gives two hoots about your customer, so long as there is real and true competitive advantage there and you can work with it in ways that are important. This places an extraordinary burden on the cultural metric. It cannot look merely at cultural *closeness*. It has to look at cultural *aptness*.

Diversity certainly is a virtue in the AVE world; we'll be counting on the metrics to tell us what kind and how much.

21.2 Importance of Language (and Unimportance of Standards)

[Because diversity is key, simple standards may be bad. Better to have a cheap way of developing adaptive interfaces on the fly.]

The same argument goes for standards and even for languages. In the case of standards, the common approach is to insist that the partner or supplier use the same set of standards that you do. Thus, you might require that a partner use a three-dimensional product model that is compatible with or generated by the same vendor's system as yours. That certainly makes life easier, and a major standards effort (STEP, the international STandard for the Exchange of Product Data) is based on this premise.

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But already there are primes in the Israeli defense community that seek out second-tier engineering shops which use specialized, deliberately non-STEP-compliant CAD tools. This is because these tools offer specific power that mainstream tools do not, and the special power compliments that of the prime. They worry about how to send STEP data to their customer some other way than getting it in that form originally.

Standards can be useful to an extent, in making it possible for partners to plug-and-play, when that will suffice, but universal standards, the standards which go through the official standards process, often constrain diversity. That diversity often reflects a cultural basis that is useful to the VE. We believe that conventions are needed, but truly agile systems will adapt special conventions only where they are beneficial.

Similarly, we can consider two models of languages, English and French. English is a federated language; it's a mixture of borrowed and invented parts, to which anyone can add for his or her convenience. It would be a mess if you wanted to administer it, but it's manifestly extensible. French on the other hand is protected by the state, its purity and stability a source of pride (and, conversely, worry about foreign influences on modern usage). We believe that there is an underlying cultural difference here that is also reflected in French and English legal and engineering paradigms, discussed elsewhere.

Agility in the VE context means the ability to be able to extend your own reach without undue cultural (and other) constraints. And we think that, at root, the other constraints (at least the non-physical ones) largely follow from cultural constraints. The bottom line is that the use of standards (especially STEP) may be a good idea for other reasons, but they have nothing to do with agility.

The *language* that VE agents use to communicate among themselves is of paramount importance. But requiring that language to be standard is unagile. Instead, we need a language that is adaptable and can be used in a basic way to describe more complex adaptations on the fly.

21.3 Hidden Economic Motivators

[Cultural factors may dominate the strategy of the enterprise. Some examples.]

Though it isn't the goal of the project to study social/cultural *motivators* in the AVE, we should be sensitive to them where they are apparent. The kind of motivators we are talking about are those which, if accommodated, could add incentive to AVEs. This, incidentally, is the converse of barriers, which is where DoD research projects usually start.

AVE motivators all seem to be cultural in nature. The relationship between culture and commerce, each providing the major force for change in the other, should be no surprise. Commerce is an older and more fundamental force in society than either government or agriculture.

Here are a few examples of such motivators:

- The Software Publishers' Association concerns itself with the pirating of soft-

ware. Approximately half of all copies of shrinkwrapped software in the U. S. are stolen; most of these in use are in business. It's known that the smaller the business, the higher the rate of payment. So this suggests a likely dynamic: the more that organizations are aggregates of small firms instead of larger groups, the more revenue will flow into software publishers.

Since a reasonable estimate of the lost revenue in the U. S. is on the order of billions, AVEs could pump large amounts into the business software market. It should be expected that a significant percentage of those dollars would go toward shrinkwrapped AVE-serving software.

- In the past, a job with a big corporation meant security. That is no longer the case. The Department of Labor reports survey results showing that most skilled and educated workers would prefer to work for smaller companies because this would make them feel more secure.

Many studies have shown that the same workers are more productive and innovative in small company settings than in large ones. So individual desire for job security (or some related benefit like supervisory justice) can be a motivator.

- Department of Commerce studies have shown that consumer preference for national brands is based on the perception of modern management rather than the facts. In other words, consumers buy Japanese cars more because they believe that they must be better because the Japanese the management style is presumed to be more *modern*.

So a VE might adopt agile practices in part because of the panache, the excitement that it adds to the customer's experience.

A corollary is that perceptions are highly influenced by cultural factors. It could be that AVEs are sufficiently modern that the modernity itself could attract consumers eager to see innovation in domestic business methods. This can be seen in the popularity of Saturn cars; people buy them not merely because of intrinsic value, but because they believe that a better system must make better cars.

All of these are social effects with economic consequences that could add incentive for the AVE. With a few strong drivers of this type, agility may not need lobbyists or evangelists. Evaluating such factors is not the target use for the metrics. But it surely would be helpful to apply the social/cultural metrics to documenting and evaluating factors such as these.

It's an area for future study.

21.4 The Role of Organized Learning

[An agile organization is one that has a learning culture.]

Agility is the ability of an organization to adapt. The AVE increases this ability by appropriately adapting the nature of the organization itself. Agility boils down to how well (meaning quickly, cheaply, and repeatedly) an organization can *learn*.

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Learning is essentially a social drama. The metrics must measure the ability of an organization to learn. We hope that they also provide a scaffolding for others to use in determining the learning path for specific types of change.

21.4.1 Honesty and the Investment Community

[The ability to judge itself seems an agile cultural trait.]

One community interested in these metrics is the investment community. The reason is simple to see. That community already has sufficient metrics to determine how profitable an enterprise *currently is*. Our new metrics (at least when applied on the strategic scale) can evaluate how profitable an enterprise is likely *to become* when situations change; and change is expected in many sectors.

For example, Warren Buffet (perhaps the world's most successful investor), above all else, explicitly assesses an organization's ability to resist the institutional imperative. This, he believes, is manifested in two qualities: the ability to learn and the quality of being honest. These two capacities are highly interdependent.

The focus on honesty results from the reward system being used to give incentive for learning. If your organization is not honest, it does not have a basis for building a reward system that is capable of promoting learning.

An area for further study.

21.4.2 The Importance of Dyadic Communication

[Even in the largest enterprise, most collaboration is between two people, a situation where social dynamics dominate.]

Essentially all of the dynamics that interest us involve communication among parties, and most of that is specifically between two parties. To an astonishingly high degree, this is between two *persons*, often as representatives of two organizations. Educated estimates range to more than half of all human collaboration is conducted through dyadic (i.e., two-way) communication between persons.

It's proposed--and we accept--that non-dyadic agreements are derived from, or special cases of, the person-to-person interaction. For example, we observe that company to company negotiations on a contract use dynamics that are similar to, or are composed of, person to person dyads.

We are greatly interested in how these dyadic interactions occur. Since our model is based on transactions between two *entities*, the metrics provides a basis for someone to leverage these cultural insights. Also an area for further study.

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22 Trust

[Trust seems to be a common cultural descriptor of agile systems. We explore the idea in this section.]

22.1 Background

[We exclude social and cultural issues from our first shot at metrics, but are advised they are unavoidable.]

The existing metrics are first-order metrics and in the first edition exclude social and cultural issues. A central issue concerning both is the property of *trust*. So the Agile Virtual Enterprise Focus Group, the email discussion group and the project looked at *Trusted Agents*. In addition to a large number of other insights, three specific topics emerged. This short report records the highlights of those topics. They deal with 1) the difference between confidence and trust; 2) the difference between trusted agents and trusted communication; and 3) trust metrics.

22.2 An Example of the Problem

[An example of an apparently logical action undermines trust. There is a difference between trusting agents and trusting the channels among agents.]

Sirius-Beta's second introduction to enterprise engineering was the role it played in automating shipboard logistics. The problem was simple, it was thought. Until the mid-eighties, ships kept records on their spare parts and manuals inventory in pencil on index cards in huge rolodexes. For all the obvious reasons, the records were poor, and difficult to track at the fleet level. The result was that few ships had what they needed and many things that they didn't. On whole, there was a vast waste in or obsolete parts in the system, which not only cost the taxpayer money (hundreds of millions), but took up valuable space and weight on the ships.

The solution, it seemed so logical, was to install modern computers on-board to perform record-keeping. This was accomplished at some cost, collecting along the way sources for many stories. The one that is cogent is that the computer systems were vehemently fought by ship's officers, and that in the first decade after installation, fleet spares readiness went way down. It took substantial effort to discover what was going on.

What had happened is that there were two spare parts distribution networks. The *official* one, which was, then and now, broken, and an *unofficial* one. The unofficial one, which was the primary channel for key items, depended on slack in accountability of the official one. Ship's officers developed communication networks based on *trust*. Those networks were an underground barter system for trading parts, which had evolved the ability to adapt while in extended cruises.

We understood the need to improve trust in the node of the system, the information support to the decisionmaker. It was a good thing to improve the quality of the knowledge about (trust in) what each ship had, and this was true for both the shipboard officers and the shorebased fleet logistics planners.

But we misunderstood the nature of the *communication* channels between nodes. Indirectly, we empowered the official communication channels, the ones which allowed shore-based clerks to carefully control what went where. These

were not then, nor now trusted to the job correctly. We failed to appreciate the power of the *adaptive federation,* agility, among officers that made the system work by applying local knowledge and domain skills.

This understanding, that there is one kind of trust in *nodes* (agents) and another in *communication* channels between nodes, is captured in the sections that follow. It would have been far better for us to improve the collaboration technology first, perhaps turning a blind eye to the unofficial parts bartering, then later have responded to increasing the confidence of official accounting systems.

Incidentally, this isn't just about spare parts. Naval warfare is a highly distributed affair, and trust among ships (meaning their officers) is essential in combat strategy. We found that the primary way this multipurpose trust was maintained and tested was through this huge unofficial parts network, which was highly personality-oriented.

We actually hurt the ability to adaptively collaborate in combat, perhaps in a significant way. Fortunately, the system hasn't been tested.

22.3 Confidence and Trust

[There are two definitions of trust. We contrast the two here.]

Substantial effort was spent by the extended AVE Focus Group in trying to pin down a definition of *trust* and surprising difficulty was encountered. Two camps emerged which can be roughly characterized as those for whom *confidence* was an adequate synonym, and those for whom it wasn't.

22.3.1 Confidence

[One kind of trust is expected repeatability. But this has problems when conditions change.]

Confidence in an agent or phenomenon means that it is consistent and predictable, based on *inductive* evidence. It is implicit in all this that you know what the behavior is. In other words, if you can predict behavior, you can trust the agent (or laws) that drive it.

Sunrise is predictable and consistent, so it can be said that one can trust the sun to rise each morning. Really what's being said is that the sun is an imputed agent of certain laws, and that you have trust in the laws of solar physics. Trust in this sense means *confidence*. But laws of physics don't change, business criteria do. In physics, one can impute an *agent* which is trusted. For instance, people often conveniently pretend that the sun causes its own rising. But one cannot do this in business because the laws are dynamic and it is important to understand the *real physics* at work.

In a business environment, confidence could mean that a prime has trust in a supplier because that supplier has consistently done well. Or the prime's buyer trusts the supplier's salesperson for the same reason.

There are two limits to this definition, and they are related. What if performance in all past experiences is not an indicator of how the supplier will perform in the

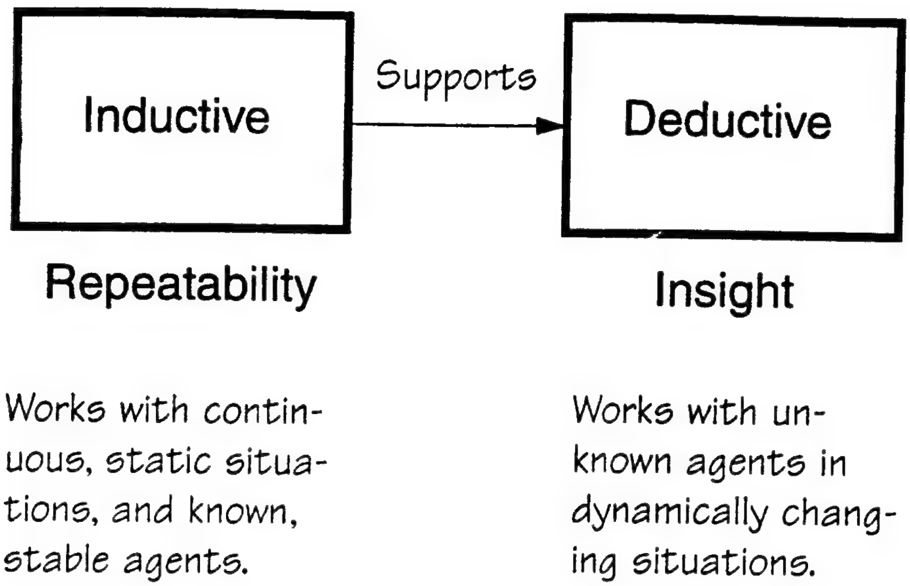

Figure 22-1:Two Definitions: Inductive (Confidence) Supports the More Formal Definition

future when conditions change? To deal with these situations, one needs a *deductive* measure of trust, not an inductive one.

The second limit is one of representation: trust in one agent may not mean that an associated, relevant portion of the system can be trusted. For instance, you may know a CEO or marketing manager well and have confidence in their honesty, etc. But does that translate into high confidence in their company's abilities?

No, it does in the *physical* world because the nature of physical causality is such that you can designate an agent (the sun, or gravity) to stand for the whole system. But in the *business* enterprise, things are not so well behaved. *Confidence* is not a sufficiently robust definition of trust purely on the limits of induction extrapolated into unknown conditions, in other worlds, the area of agility.

Also, using this notion, there are difficulties in who could be designated the agent which represents the portion of the (business) system which is of interest.

22.3.2 Trust

[Another notion of trust is based on knowing how someone might behave. This is better for agility.]

Another, better notion of trust is based on *deductive* criteria. On its face, this is what we would prefer in engineering agile business systems (as with non-business systems). Using this notion, an agent is trusted if he/she is:

- *Accountable*: this is another way of saying that the agent is causally coupled into the processes in a tight, understandable, causal way. (We expand this one

issue below in talking about channels.)

- *Timely*: the agent's insights are based on the current situation.
- *Accessible*: the agent, specifically the agent's insight, information or knowledge is accessible to you at your convenience.
- *Accurate*: the agent's insight is correct. It's the *truth*.
- *Complete*: the agent's insight has all of the necessary context and qualifiers to allow you to perform your system-level analysis.
- *Uncorrupted*; the agent's insight does not have junk mixed in with the truth.

For example, take a supplier's marketing representative. (Note, all mainstream examples would involve agents as people.) We could really like this person, appreciate his/her ethics, and have had nothing but good experiences so far, and still not have trust in the company under an unusual demand. (Not having trust is simple neutrality as opposed to negative trust: trusting that the company will screw up.)

For the marketing agent to be *accountable*, he or she would have to fully know and honestly represent the capabilities of the supplier to your own level of detail. The information would be *timely* if it represents the current state, not an extrapolated, perhaps hoped-for state. It will be *accessible* if you can get what you need when you need it. Your trust in *completeness* and *uncorruptness* means you're getting the whole truth and nothing but the truth (see below. If all these things are true, you have a *trusted agent* as a collaborator in engineering your supply chain.

Incidentally, our definition of deductive trust includes the requirement that the information be accurate, complete, and uncorrupted. This same notion is captured in the oath that witnesses take in U. S. courtrooms in order to establish trust. The witness swears to tell *the truth, the whole truth, and nothing but the truth*. What's the difference?

The truth means that what will be reported will accurately reflect what is known. The *whole truth* meant that the statement will be complete. An omitted but essential qualifier or context for example could completely change a *true* statement's meaning. While the witness told the truth, it could be missing key ingredients which have the effect of making the true statement less true. *Nothing but the truth* is the reverse, where the witness adds statements which, while not untrue in themselves, add false qualifiers or context.

This is the notion of *deductive* trust which we use in the reporting the following additional observations.

22.4 Agents and Channels

[Trust in agents is different than trust in the communication channel among agents.]

There is a distinction to be made between the *agent* and the *channel* through which you communicate with the agent. Each has its own type of trust. You have to trust, for instance that the sales manager of your supplier knows what's up, as well as having to trust that the email that you got from him/her is at sufficient fidelity. One is trust in an *agent*, one trust in a communication *channel*.

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22.4.1 Agents

[There are three types of agents.]

We delved into this somewhat because the focus on the communication seems to be the second main distraction in this whole dialog (the first being trust as confidence). Trust in communication is where a lot of VE effort is being placed: assuring fidelity and controlling access through the channel, the whole Electronic Commerce diversion. But those are relatively simpler issues; the key payoff is in whether the *agent* is a trusted one.

We've broken down the agents into three types:

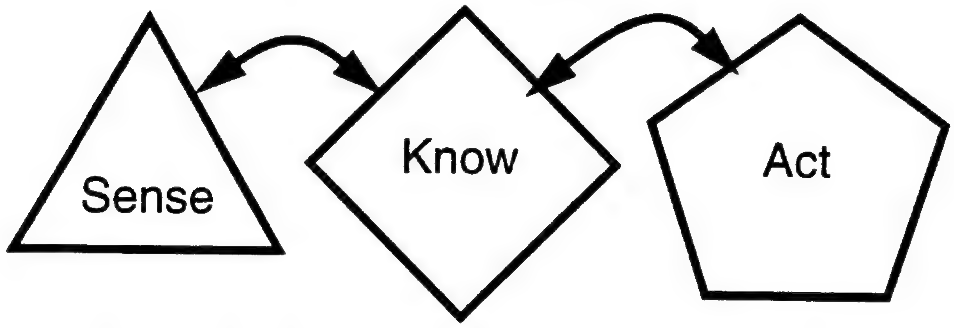

Figure 22-2:Three Types of Agents in the Enterprise

- The *Sensor*: this agent is alert to all the factors that are in it's assigned domain. Trust in this type of agent means that the signal is true. If kids stop buying white sneakers in favor of blue ones, you want to be able to trust that your market researcher detects the trend (and doesn't signal false trends).
- The *Analyzer*: an agent that determines whether a *change* (or other input from the sensor) is important to the enterprise and in what way. A trusted analyst is rare unless they stick to the most mundane of factors (cost, quality) and stay close to home in terms of existing products and strategies. This agent is the target for the agility metrics project, the metrics intended to increase the ability to audit reasoning about strategies of change, thereby increasing trust.
- The *Actor*: the agent that triggers and controls the process, which in the agility sphere is a process of change. A trusted actor is one that takes the right action and does it effectively.

Often two roles, and rarely three, are played by a single person.

So, there are three types of agents and three criteria by which they become trusted agents.

22.4.2 Channels

[Agility is related to the connectivity among agents.]

The agents are connected to each other by communication channels, both *horizontal* channels; links among sensors, analysts and actors, and *vertical* channels

which link agents to form a the VE, or an enterprise for that matter. All of these channels are of the same type regardless of what agents they connect. All are subject to the same problems, and probably all addressable by the same policies and technologies.

Usually, the vertical links in a VE involve only actor agents. If many of those actors are not connected to analysts, the system cannot be agile. Probably, what makes an enterprise better, including more agile, is if there is not only many channels, but if:

- they link across all three types of agents
- they cross functional and company boundaries
- there is a high level of *trust* in the agents (and of course the channels too)

Therefore, a rule of thumb for AVEs is to have high connectivity and trust among agents.

In most cases, a network of agents operates at the lowest level of trust of any of its components, unless there exist some metrics to evaluate the trust of specific agents and annotate messages from that agent accordingly. Current metrics, not ours, deal with some elements of the channel and the simple notion of trust we noted above called (inductive) confidence.

22.5 Trust Metrics

[Our basic method might be expanded to provide metrics for trust in an enterprise, which are also tagged to processes and agents.]

It is not within the scope of the metrics project to address *trust metrics*, just metrics of agility. But it is entirely possible that much of the work on agility metrics can be leveraged to develop metrics for trust.

Our new agility metrics are based on an information-theoretic idea that the more complex a communicative (functional) network is in certain ways, the more resistant to change it is. Among all the complexity metrics that exist, we've distilled some that indicate this resistance. These themselves are functions which we can manipulate in mathematical ways that are being explored by our Tool Strategy.

The information-theoretic view depends on breaking business processes down into *agents* and *communicative acts*. Agents in that view are the same as the agents we describe above. Communicative acts follow the channels we described above.

In fact, the agility metrics deal with measuring the *connectedness* of agents, but depend on a single level of trust among all agents.

However, this breakdown of agents and channels is just what we've been using in our trust discussion. It's likely that much of the foundation of the MAVE project can be used by someone looking at trust metrics:

- The mapping of business processes to agents in a practical way (via the AVE Focus Group Reference Model).
- The understanding used to map theoretical complexity metrics into specific business strategies

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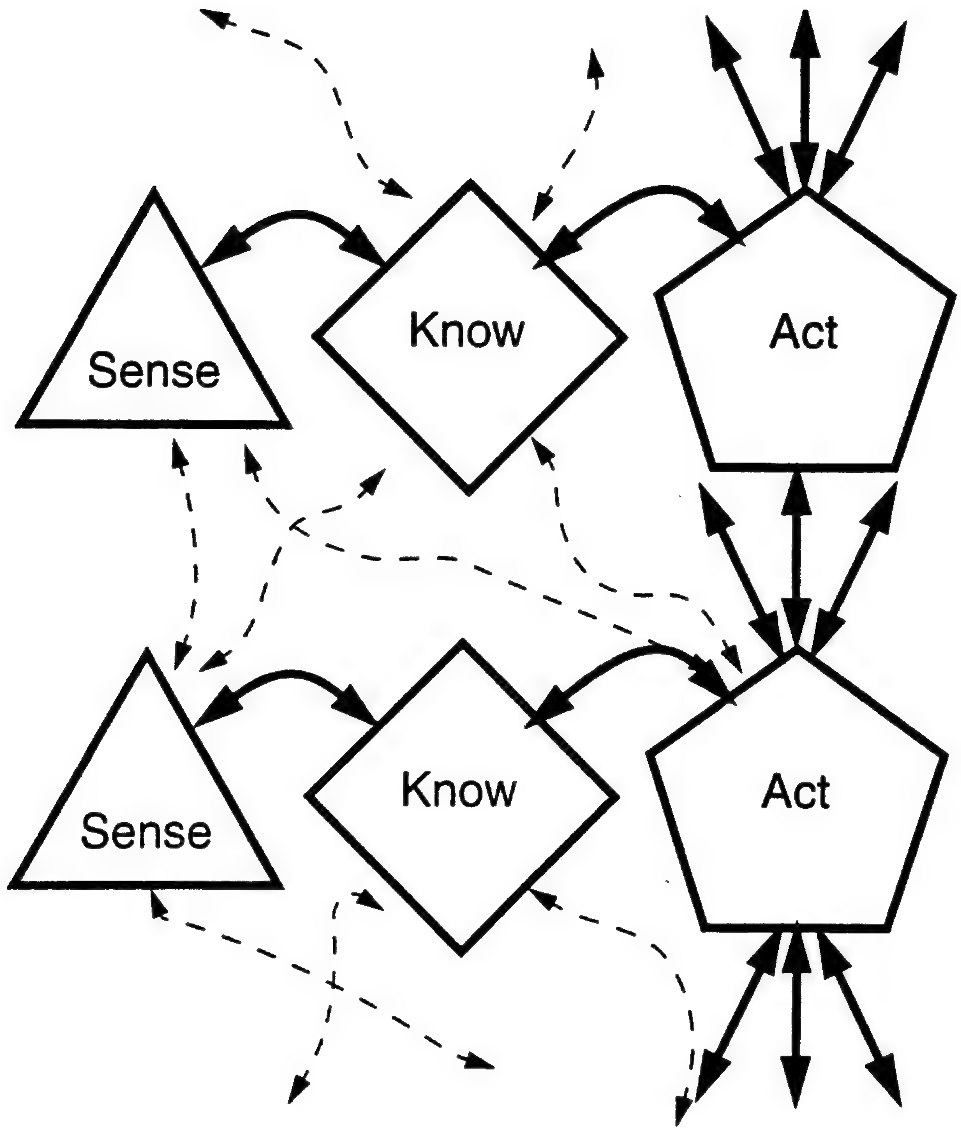

Figure 22-3:Different Types of Channels Interconnect the Agents in an Enterprise

- The anticipated advances in modeling *soft* (social and cultural) processes which come from the marriage of communicative acts and situation theory.

Incidentally, the case study provides some information on the cost of creating this breakdown, which would be reusable for trust evaluation.

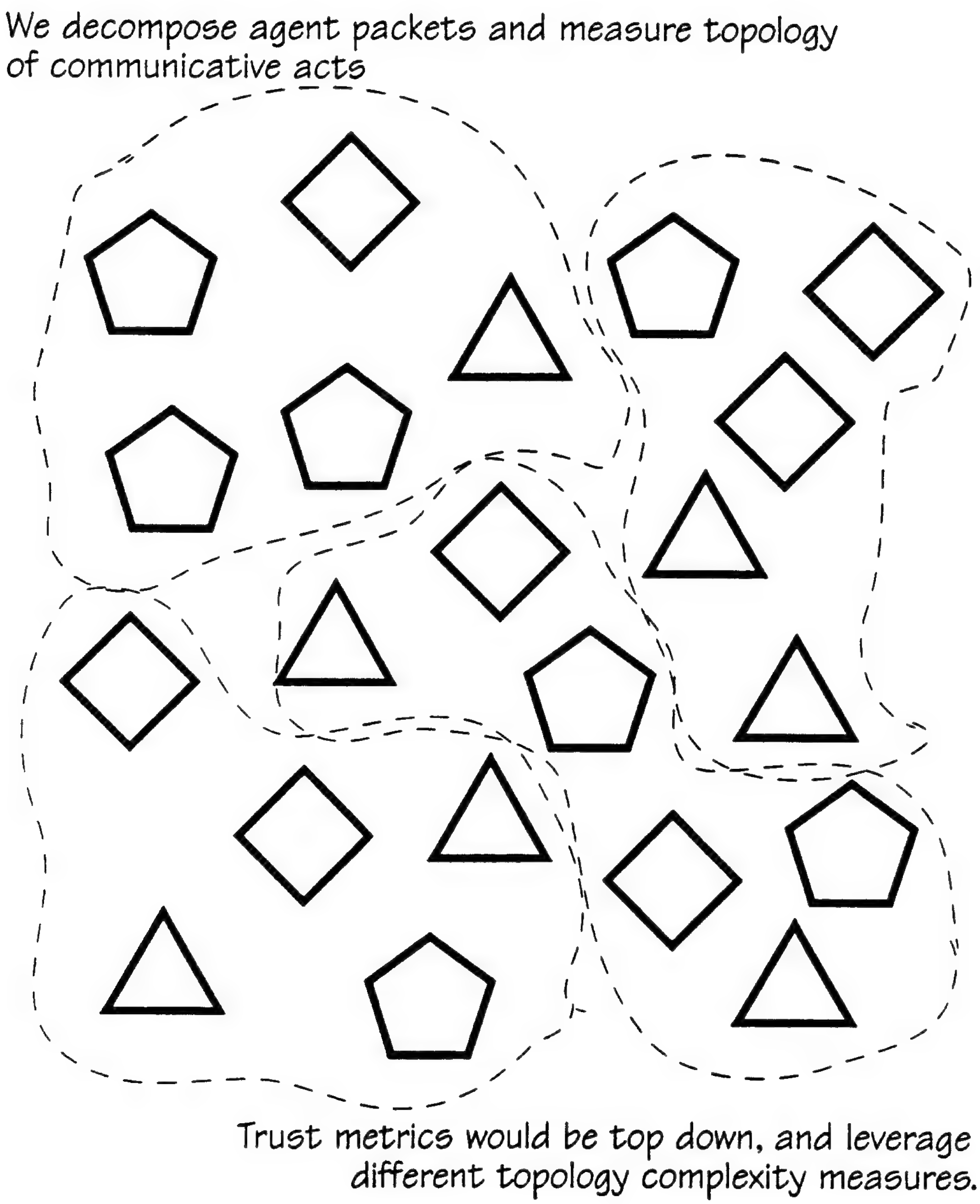

Figure 22-4:Our Decomposition of the Enterprise into Conversations among Agents can Support Clustering for Trust Metrics

23 Cultural Drivers for Legal Issues in the Defense Community

[We suggest a source for two conflicting paradigms which haunt the defense industrial base.]

23.1 A Key Difference: The English and French Engineering Paradigms

[The French and English have wholly different approaches to engineering. These are culturally based. The U. S. civil sector inherited the English, while the military sector inherited the French.]

Our mandate included looking at potential differences between the civil and defense manufacturing communities. We've done so, and concluded that the differences are in the contractual and regulatory infrastructure. But what causes this are deep-seated cultural differences. This can be seen in engineering approaches.

It happens again and again that engineers from a commercial perspective look at a problem and produce differing results from those of engineers associated with defense or government. Variations on large water projects, nuclear power installations, and the Strategic Defense Initiative are a few of the generally recognized high-difference areas. Certain of the less public ones involve environmental and transportation engineering risks, and some argue that the effect is also seen in health and criminal risk analysis.

Of the differences which one encounters, those which are most interesting are not the ones arising from varying priorities or politics, but differences that run so deep in world views that they seem to underlie the actual mathematics. We count ourselves among those who believe that the difference can be traced to a well-recognized difference in engineering traditions between 18th-century France and England.

In *England*, engineering grew out of a strong guild tradition, which stressed commercial practicality. Engineers and civil servants rarely mixed. Even in the military, where the use of engineering skills was heavy, the tradition was to keep a distinction between warriors and engineers and to utilize contractors where possible for engineering tasks. Having engineering skills provided scant introduction to either military or political society.

In contrast, *French* engineering touted its origins in the mathematical elite, many of whom in the eighteenth century were French. Military officers were expected to be competent engineers, and civil and engineering life were strongly intermingled. For example, the French established the world's first engineering university in 1794, the École Polytechnique, on Rue Descartes (see [DEVL97]!) no less.

Championed by Napoleon, the school and the graduates were hailed as the hen with the golden eggs for France. That literally has been their symbol since. This was in fact a military school; aspiring engineers wore uniforms, carried swords, and drilled. The lower tier students studied at the École Centrale des Arts and Manufactures and were destined for mere commerce. The upper tier went on to graduate work at the École Ponts et Chaussees (bridges and embankments) and became known as ingéniers de l'état. These men had profound influence in the bureaucracy, and hence over all of French society.

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The French model of engineering, therefore, evolved with large, often extremely expensive, ambitious, and visible projects. These were designed to serve the society as a whole, and the benefit to the engineers was in advancing society. It would have been considered crass to have applied values of personal profit to any project, which, of course, was the English default.

The French invented the engineered organization--the bureaucracy--but only later in far richer and larger countries (The U. S. and USSR) would their ideas on both engineering and civil management become supercharged as the prime technique for conducting the cold war.

Of course, being an English colony, America, especially New England, followed English tradition as its industries grew into the 19th century. But the French tradition was inoculated with amazing effectiveness in both American and Russian militaries.

Russian czars were eager to europeanize their nation and so entered into a long exchange program which continues to this day. Engineers and bureaucrats were sent to France for study at the Polytechnique and imported the paradigm back into their country. Surviving the revolution, the paradigm was well suited to the Soviet totalitarian direction events took and especially came into play after WWII as the entire country had to be *re-engineered*.

Communism, social engineering in a very basic sense, can be linked to this paradigm, and many believe that it wasn't war, boneheaded and cruel dictatorship, or socialism that killed the Soviet Union. Instead, it was their blind following of massive, centrally managed engineering projects for the common good, without the feedback loop for immediate, finegrained satisfaction that market forces provide. Perhaps most disastrously, even agriculture was centrally *engineered*.

At any rate, the British model dominates American commercial life, essentially all of our economy, and has been quite successful because innovation has been linked to personal reward. But the French model gained a toehold. How and where (in the military) is instructive.

The U. S. was losing its war of independence. The English nearly had it beaten, but the intervention of the French at Yorktown in short order proved decisive. The primary asset the French sent: military engineers and sophisticated materiel. The apparent lesson was not lost on General Washington, and among the first acts of the new nation, which he ramrodded, was the decision in 1778 to establish an engineering school. This was finally established at West Point NY in 1802.

Modeled directly after the École Polytechnique, the school was dominated by imported French professors. Its mission: to produce engineers for the nation, incidentally through the army, which was seen as necessarily synonymous with technological progress. Of course, over the next few decades, more and more nonengineering and scientific subjects were introduced until we have its current state.

But meanwhile, the English inspired idea of *practical science* caught on in the U. S. commercial sector. The two traditions competed, each dominating in different regions of the country. The French model was adopted in the north, with the establishment of an engineering school at Rensselaer Institute in 1835. By midcentu-

ry, Rensselaer was the leading engineering school in the country. The reason this French approach flourished was the same as for the school's founding and success--the railroad.

Railroad monopolies (for our purposes, the same as government agencies) needed engineering skills to build a vast network, including many challenging bridges. The idea of large, centralized projects serving the institution was very French.

In the south, the English model started to grow from grassroots need. The two first universities, in fact the centers of schooling in the south, were the Universities of Virginia and Alabama. Their model of commercially-driven engineering directly contrasted to that of West Point and Rensselaer and was so noted at the time in competitive recruiting pamphlets.

Alabama's initiative was destroyed by the civil war and never recovered, and it is known more widely today as an athletic franchise. But what happened in Virginia is really interesting. The head of their *practical science* program, in fact the only full-time professor in it, was a young fellow named William Barton Rogers. He was trained at William and Mary. (Together with Harvard, they were the only two advanced schools in colonial times.) His father, being a chemistry professor there, knew Thomas Jefferson who considered the founding of the University of Virginia to be his finest achievement, instructing that only that fact appear on his tombstone, nothing about his role as a founding father of the U. S. (The instructions were not followed.)

Jefferson believed that the country was making a mistake going with the French model at West Point. He had spent several years in France as the U. S.'s first ambassador and had made a careful study of their model. He considered it insidiously undemocratic. He very much wanted *his* university to grow as a school based on the English model and often promoted that idea at William and Mary to the senior Rogers until Jefferson died in 1826.

So here was Barton Rogers, leading the charge at the University of Virginia in 1846 trying finally to do so. But he left. The University had hired a Jewish professor that year to teach Hebrew and Greek for Biblical study. The student body was so intolerant that they pistol-whipped the new professor. When the dean passed a rule outlawing guns in class, unruly students shot him! This thuggishness coupled with the institution of slavery was too much. Rogers decided to take his mission to a more enlightened locale.

He spent a few years proselytizing this idea of a school for democratic/commercial engineering and practical science, including during a stint as president of the young American Association for the Advancement of Science. Finally, he established MIT, then Boston Tech, which quickly became very strong, and providing a model for linking innovation and science, which permeated through civil society and commerce.

Supporting this development were strong Emersonian ideas, local to Boston, of the importance of individual principle and intellect, as opposed to those of an institution. Around 1880, more international students were drawn to MIT than to

the Polytechnique, signaling a change of values in Europe, the emergence of the English model of innovative commerce.

While the Russians became thoroughly French, the U. S. developed a bicameral paradigm, with French dominance in various governmental and military affairs. The French tradition can be seen through the large centrally-run projects of the Army Corps of Engineers, which began in the early 19th century with a national system of canals and lighthouses, and was revived with the production miracle in Dayton concerning WWI aircraft. It was further sustained between the wars by large hydroelectric programs and continued through the nuclear bomb and energy projects on through to the Apollo missions. The tradition can also be traced worldwide, with the French often leading the way, as with the Suez and Panama canals.

Such influence is clear today in every U. S. weapon system and throughout the defense industrial base. A recognition that a completely different engineering paradigm is at work becomes a prerequisite before any enlightened comparison can be made between business processes and the underlying culture in the defense industrial base. We think any attempt to bring commercial practice to the defense domain should acknowledge the 200-year battle between these memes.

Military electronics and software, for example, differ from their commercial counterparts in profound ways. The conventional thinking is that their requirements are different, so a different culture has emerged in response to each. We propose the opposite--that the cultures came first.

Notably, whenever agility is required in the defense base, an English-type organization is introduced into the system. Thus the nuclear weapons complex has its Sandia Labs and the defense aircraft has (or had) the Lockheed Skunkworks.

23.2 Lessons for Metrics

[Defense lack of agility is caused by French at the top, English at the bottom of enterprises.]

In the dominant defense (or French) model the product, the processes, and the skills used to support the processes, as well as the work breakdown of the processes, are all specified by the customer in a centrally-managed top-down fashion. In the commercial (or English) model, a fine-grained, bottom-up collection of functions, is empowered by market forces. These functions are empowered to change all of the noted items (products, processes, skills, work breakdown) in a way that manifestly results in better, faster, and cheaper products.

So, it would seem that a lesson emerges here for agility metrics in the defense sector. The transactions that are supported must include those that deal with this idea of market forces (the linkage of value added for recompense) adjusting the processes. For example, a transaction boundary between a prime and a subcontractor is less agile if the prime insists on control of details of the processes that the sub uses.

Consider the example of the Sidewinder. The Soviet AA-12 VE ran under a French paradigm throughout and was effective; the Israeli VE was thoroughly English and was equally effective. It's when you have the top half (customer to prime)

with one and the bottom (prime to subs) with another as in the U. S. that the system becomes crippled. Compare the French/English breakdown to the *meme-classes* of the structured controversy brainstorming method.

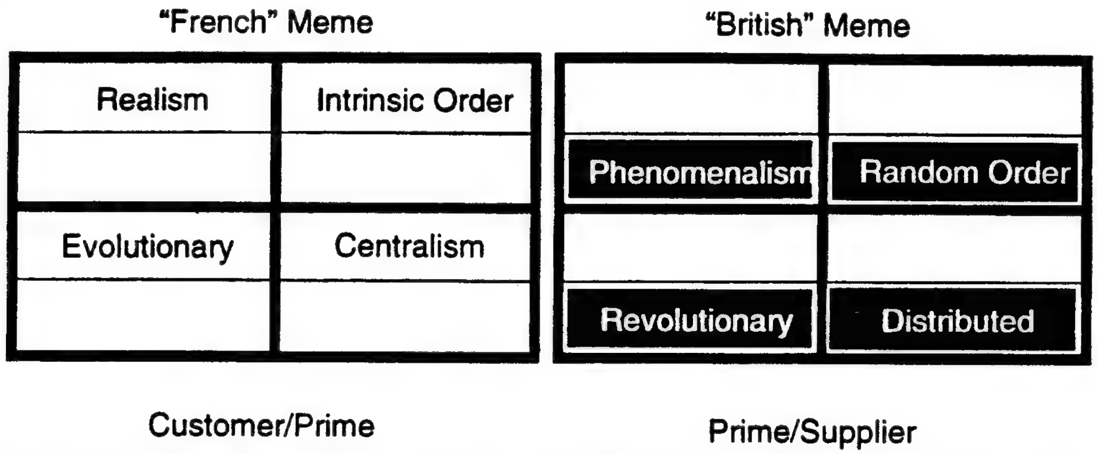

Figure 23-1:French Meme from DoD to the Prime, English from the Prime to the Subcontractor

23.3 Law Follows Engineering

[The two engineering paradigms become ensconced in two differing legal systems, also culturally based. Case law (as in the movies) is a trust-enabling environmental factor.]

Around the world, we find two primary models of how law is built, and these differing law systems correspond closely to the two government/engineering trends discussed above.

The type of law many people immediately think of is *code*. This originated, as far as we know, from such early examples as the Babylonian Code of Hammurabi, and this approach became incorporated in many later hierarchical societies, their governments, and religions (including Judaism, and thence to Christianity and Islam).

The idea is that some wise person or body is *in authority* to make law. These (usually) men proscribed conditions relating to certain situations. If a new situation--one not originally anticipated--arose, the authorized body would expand the code. Code was the basis for Greek and Roman law, which has been inherited by much of the western world.

Opposed to code is an idea that originated with Darius (about 500 B.C.). Darius organized the Persian empire based on the idea of federating many states (satrapies) while preserving the local cultural diversity. The idea was that no one could make comprehensive law from the top down; there are just too many special conditions and local exceptions. So the idea of common (or case) law was developed.

It was used by segments of European societies which were on the outside fringes of the Roman empire, notably the Celts (in the British Isles). Beginning with the

famed Magna Carta, and evolving into its present form by the 17th century, common law made a comeback, in Britain and the British Empire.

The key idea is that a jury of common people could evaluate a situation and extend the meaning of prior law as made by a legislature. That judgment then became a *case*. Subsequent juries were to consider both the original law and the subsequent case with equal weight. Over time, of course, the cases would often grow to eclipse the original law, resulting in a bottom-up, dynamically-redefined basis of laws that were self-adjusting.

Several advantages resulted, but the one that interests us here is the simplicity of contracts that this allowed which we noted in the movie example. Instead of having to write a contract that covered all possible contingencies, one only had to record what was really intended by the agreement. The large body of cases that was presumed to exist and to be based on common sense justice, instead of bureaucratic foibles, could be called upon to adjudicate differences if things went wrong.

This increased the burden of the trial system, but greatly decreased the burden on the contract law system.

The U. S. inherited this system of common law when it transformed from an English colony, one of only a few countries to do so. Actually, each of the now fifty states individually inherited this system, and have evolved fifty similar threads. Federal law issued by the central government now, however, tends to be code-oriented. For example, the Uniform Commercial Code was needed to expedite interstate commerce, and it deliberately concentrated all facets of making the law in a few, powerful bodies.

So, today, there is a mixture of code and common law in the U. S. But most provisions of most contracts in the commercial arena rely on case-based state laws. Some commercial sectors can be very agile in their contracting practices because this situation still obtains. The bad news: Americans go to court more than anyone else. The good news: in some sectors, the decrease in the cost and time of devising domestic contracts is vastly less than in, say, Germany and Japan, our current international competitors.

This is a system in which whatever lack of trust among the parties is handled by a presumption of trust in the case law, rather than in the corporate lawyers. We believe this to be a structural advantage for the U. S., and especially so in the AVE context.

Defense contracts not only are code-based, but more centrally-mandated than any other sector of the economy. The contracts are based on code, the Federal Acquisition Regulations (FAR). Worse, the combination of the French engineering paradigm results in every detail of the product and process being detailed in code, through specifications.

Engineering decisions about processes, skills, and work breakdown which elsewhere are fluid are captured explicitly in the contract and supporting law. The result is a brittle, unagile system that cannot respond, for example, to a severe missile threat in a timely way.

We believe that these competing influences cannot be wished into harmony. Indeed, many benefits result from the institutions that exist. The challenge is instead to create greater agility within the existing situation.

24 High Concept in the Supply Chain

[We return to movies to examine lightweight contracts as a portable technique.]

24.1 Background

[We revisited the movie contacts.]

Consider this as a continuation of the Whaling Story. In that story, we suggested that the U. S. film industry was both relatively agile and a good example of continually formed Virtual Enterprises. We proposed that though successful, this was somewhat accidental, relying on lightweight, code-based VE association contracts. It seemed then that there were some elements in this natural evolution that could be engineered into other industry sectors, but the point of our effort was elsewhere, in developing metrics.

Since then, I've burrowed deeper into the situation, developing and exercising insider contacts. All of this has been more difficult than you would think, because the agility *evolved* rather than being engineered, as we propose for example in the defense aerospace sector. Few movie managers know what's going on at the level that we find useful. Much of what follows was jointly discovered by us working with them.

Elsewhere, we report on *Trusted Agents*, with much of the discussion concerned with how an AVE is formed. So, in revisiting the movie business, we wanted to particularly touch on what we could take away in *engineering* an agile supply chain, an AVE, and also contribute to the discussion on trust and change concerning agents.

24.2 The Movie Industry as a Prototype

[The Japanese consider the movie business a portable prototype, both after the war and more recently.]

A brief history: not so long ago, the 30's, the movie industry was configured like today's automobile and aerospace industries. The market was dominated by a very few large, stable companies. The *big five* were: Lowes/MGM, Paramount, RKO, Twentieth Century-Fox, and Warner Brothers. They were deeply vertically integrated, including control of the distribution by ownership of theaters.

Competition among them drove them to what today we call *lean* manufacturing practices: flat organizations, prequalified suppliers (in which they often had an interest), a version of just-in-time practices. They were leaders in novel accounting practices, using what clearly today can be seen as activity-based costing (but without the glitz).

The height of this trend continued through World War II. After the war, Japan had the opportunity to engineer an industrial policy. We were told by a key man in devising that policy that they studied and refined techniques from three sources:

- *The British system of civil service and empire governance*: This system, which the British based on Persian models had been internalized during the war to facilitate their imperial ambitions. But because of the way they mix government and indus-

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try, it became entrenched in business. Key discriminators here are flat organizations and decentralized power.

♦*The U. S. food distribution system*: The just-in-time movement from California, where most of the produce was, to the East Coast, where most of the people were was heralded world-wide as a miracle.

(Incidentally, current attention is focused on the ***Iranian*** food distribution system. In the U. S., everyone along the literal food chain can get paid when their product or service is delivered, because money is ***borrowed***. But in Iran, islamic law forbids usury. There is an advanced experiment underway that makes each member of the supply chain a partner in shares, who gets reimbursed when the product is sold. The value of the product (including how much survives the pipeline) isn't resolved until the point of final sale. This makes the supply chain more attuned to the strengths of balancing market forces.)

♦*The U. S. movie industry*: This sector had several attractive features. It was more profitable than other sectors; it mixed culture and business in an apparently leveragable way; and its vertical integration extended to the customer. Japan knew that it had to establish a new model, selling to customers abroad, and was interested in how the engagement of customers could be engineered.

Only the latter two were publicly discussed with the occupiers. General MacArthur, as the military governor, facilitated building an infrastructure based on these principles. You have to understand that before the war, Japan was controlled by a few powerful families in feudal organizations, *zaibatsu*. MacArthur outlawed these, to be later convinced that they should be reinvented as *keiretsu*, vertical corporations modeled after the zaibatsu, but with what he though was the democratizing, western ingredient of market pull. Deliberate emulation of the movie business was the model which convinced him, applied first to the shipbuilding and then the automotive sectors.

The principles they extracted from food distribution and movie production benefited greatly by being abstracted from their originating domains; the process formed the basis of a set of engineering principles for enterprises. Later, when the much refined principles were abstracted back by the U. S. from Toyota and other Japanese automakers, we dubbed the collected diverse principles lean.

The point we are making here is that the movie sector in the past has successfully served as a model for VE engineering principles. We'll note below that the movie industry changed since then. While the U. S. lost its steel, machine tool, consumer electronics and shipbuilding industries, and took big hits in the automotive and semiconductor sectors, Hollywood completely dominates its now greatly expanded domain.

All of this is another story than my point, but let me sketch just one more chapter in the Japanese thread. Akio Morita, the founder of Sony, was knowledgeable of, and extremely interested in this history. He followed Hollywood closely and was convinced that Americans were not aware of (what we now call) the agility principles that had evolved of themselves right under their noses; also that Japanese restraint and circumspection could turn these into a new generation of enter-

prise engineering principles. In *The Japan that Can Say No*, he suggested that a new handle for world dominance could be contrived.

Sony purchased a major Hollywood studio in the late eighties, Columbia, for twice its worth, the one most closely associated with the High Concept ideas noted below. To run it, they hired executives whose only qualification was their association with the technique. In announcing the acquisition, he briefed the *kisha club* (the exclusive Japanese insider pool), citing the MacArthur legacy and pointing out a new model beyond lean. He presumably did the same within *keidanran*, the business association widely considered the true power in Japan. This led to his election as chairman.

Matshusita immediately followed suit, buying MCA/Paramount. Instead of slow osmosis of concepts and philosophy, they pushed harder, selling out at a loss soon after. We mention this in our Waterworld example. But that's another story.

24.3 Hollywood Evolves

[Hollywood develops the packet-unit production system, a virtual enterprise system. It depends on a culturally based trust communicative shorthand.]

Meanwhile, back to the Hollywood of the late thirties. The U. S. broke up the movie enterprises, based on antitrust concerns. (This seems anachronistic today, comparing the then five equal competitors to, say Microsoft.) Distribution and production functions were severed, breaking the link to the customer which was well understood. Other factors intervened; it's an interesting case study. The result was the evolution of the packet-unit system. This is one example of what we've been calling the VE: the prime identifies the market need, providing the plan, the intellectual property that addresses that need. It also arranges financing, which includes providing the highest capital items.

Production assets, formerly owned by the companies, were distributed in many small companies which could be quickly assembled to produce a film, the VE dissolving immediately thereafter. It took a little while to optimize this system to the point that it exists today, hugely successful. (Americans spend more on entertainment than on defense and education combined.)

Novel ways of sharing risk (distributing financing), managing liability, and exploring new ideas have been developed. But what concerns us here is the method which evolved to understand and deal with the customer after the prior connection was broken. It's a much studied technique called *high concept*.

24.4 High Concept

[High concept defined and proposed as an agility strategy.]

The idea appeared in the mid-seventies and utterly dominated the U. S. film industry for a while, and is still dominant. A high concept film is one which is based on a succinct and deep description of the product, all elements of the product that would be valued by a customer. Movie products are complex, involving several exhibition modes of the film (theater, TV, tape, both in the U. S. and abroad), as well

as associated music, book, toys, theme rides, etc. High Concept is so named because it ties all elements across these media and all elements within the product (story, stars and such) into one clear statement of philosophy and style.

The underlying assumption is that the customer's need can be tersely, understandably and logically characterized, *modeled*. That understanding, however broad and involved, has a simple core, which by itself covers all the important element of the project. To quote Stephen Spielberg:

> "I like ideas, especially movie ideas, that you can hold in your hand. If a person can tell me the idea in twenty-five words or less, it's going to make a pretty good movie."

The conventional wisdom is that a High Concept film is a stupid film, catering to a feeble, lowest common denominator. But it's persuasively argued that this isn't necessarily so. *Jurassic Park* is no more a high concept film than *Schindler's List*. As we say, the notion of high concept is thoroughly studied in film schools, and consistently practiced by producers, who are organizers of the VE. It's also considered difficult to master.

In all these considerations, the primary purpose of the High Concept description is to guarantee that the movie (and associated stuff) has each stage of its production targeted to how it can be successfully sold to the public, meaning it has a concise tapestry of hooks for marketing. Naturally, just being High Concept doesn't guarantee that the film will be good, or successful, just that it has a shot (at success at least).

To repeat: everyone in the industry understands High Concept as a way of modeling the customer's need/desires, managing constraints and coordinating a coherent, understandable response. Its considered a device for marketing, with the emphasis on the link between the prime (meaning the producer) and the customer. It also helps a prime understand its core competencies, and special strengths; the kinds of films a studio plans are often described in High Concept terms. In other words, it is a description of a strategy to reach customers *in terms understandable to the customers*, which the producers use to form a profitable link with the customers.

In shorthand, a High Concept description is succinct: *Flashdance* was a *Rocky for Women*. Almost always the description builds on prior experience, and familiarity with the precedents is culturally necessary for membership in the community. However, masters of the High Concept develop the description to an arbitrarily deep level, with specific tailoring for each of the major disciplines involved.

Recently, in analyzing how a few studio heads consistently ripped off conglomerate investors buying the studios (including Sony!), High Concept has been implicated in a different link, sort of up the ownership food chain. It's an interesting story; the value of the production house was artificially inflated by mastery of High Concept techniques.

One can clearly see a simple reflection of High Concept in the current fad for *mission statements*, which firms use to describe themselves to their investors and stockholders. It's small potatoes compared to how well developed and fluid High

Concept is in films, but the same idea. However, that use of High Concept is not cogent to agility.

Working with the movie people, we think we have helped uncover an unacknowledged but perhaps critical role of High Concept in another link: the culturally-based relationship among the prime and its subs in forming the VE. It's described here for the first time.

24.5 High Concept in Organizing the VE

[We report on how the cultural shorthand enables agility.]

24.5.1 What it Does, How It Apparently Works

[High Concept depends on and feeds its cultural base.]

All studios currently use the packet-unit system of production which essentially means that for every picture, a new VE is created. Much to the surprise of the studio with which we were working we found that the formation and operation of the VE was more agile when a good High Concept for the product existed.

When the AVE Focus Group created the AVE Reference Model, we paid particular attention to the need for a clear definition of the opportunity, the strategy anticipated to address the opportunity, and the ersatz corporate culture of the VE. Given this, we felt that the scope and role of each partner could be teased out; when the opportunity changed, the change in its description can direct changes in roles and responsibilities of each partner.

High Concept fills that role nicely as a tool in building an AVE. The techniques and institutional support which have evolved around the High Concept idea in a very large industry might be instructive, and applicable to, say, our initial target domain of the defense aerospace industry.

To recall: in a movie VE, it's composed by dint of agents. Some are agents in the showbiz sense, individuals who professionally think and negotiate for writers, actors, directors and sometimes other major participants like cinematographers. Labor unions are key agents, since they provide and certify appropriateness of, a majority of the participants to the various companies involved. Some of the agencies are not human, but are gathering mechanisms where High Concept search and exposure can be accommodated.

Success on a film, including keeping costs low, depends heavily on everyone having the same idea of the style and purpose of the product. Partners are evaluated based on their experience with and understanding of elements in the High Concept. To an astonishing extent, the High Concept fully serves as a script of sorts that the agents can use to quickly and competently stitch together scores of VEs per year.

We see the High Concept statement as a tool for binding to the customer as a result of losing the institutions (moviehouses) that were there in the 30õs. Similarly, the High Concept is a tool for binding to temporary production assets in lieu of the in-house production assets of times gone by. So, it can be seen as a way of

binding the various small partners to the customers *in the context of the whole system*.

24.5.2 Connection to Lightweight Contracts

[High Concept is the context for trust.]

The central feature of the High Concept is a description of *style*; High Concept films themselves are dominated by style. In the High Concept definition are all the cogent elements of the soft stuff both in and behind the product. That is to say that High Concept captures the *feel* of the picture as part of its product description. Elsewhere, we talk about a structural advantage the U. S. has in building VEs in its code-based contract law, and how Hollywood utilizes that advantage.

High Concept provides a scaffold around which these lightweight contracts can be built. A good contract is an agreement of what the parties will do, what they intend to accomplish. The contract's primary value is in recording the agreement, but the agreement is eminent. The deeper the agreement, the better the VE. The High Concept is both a collection of concepts around which two parties can agree, and also a text representation of what those concepts are.

Movie concepts are lightweight because they rely on the High Concept for all the hard to capture, soft part, add some quantitative stuff (so many carpenters, so many days...) and leave the exceptions largely to pre-existing culturally based case law (or its equivalent boilerplate).

24.5.3 Agents in the Strategy

[Agents are empowered by this shorthand, agents keep the culture vital.]

A discussion of contracts is a discussion of trust. In building the VE, you need to identify the agents required to build and maintain the VE and determine what it means to trust them.

The way that High Concept definitions are put together depends on a notion of who does what, so the identification of agents (at least types of agents) follows directly. For instance, if a detailed High Concept for a science fiction film (as part its style) required flying monkeys you would have one or more special effects agents to approach to discuss which among differing processes best achieves the effect. It would have to be consonant with the desired overall philosophy (and their constraints: time/cost) and you'd have to know who could do it.

Those types of agents have evolved in the system. They *speak* High Concept as a cultural attribute. They tend to be trusted in several ways:

- There's trust in their *integrity*, in the sense of conforming to ethics, morals and values. The penalty for breaking this trust is ostracism. This type of trust is independent of the High Concept idea the way we're using it. But in interviews, members of the community spoke of these ethics, morals and values in very much High Concept terms. There was a widespread belief that Jewish religious and social traditions provide a historical basis for this.

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- There's trust in the ability of the agent to get it, to *understand* and internalize the High Concept, translating it into the technical needs of the agent's area of expertise onto the vocabulary of suppliers of which they are aware.
- There's trust that the right supplier, artist, or whoever has been *selected* by the agent. A poor experience with a partner translates directly into a negative for the agent. This is inductive trust, while the others are deductive.

Agents can be completely independent persons or companies, they can be representatives of one or any potential performers (as in the Creative Artist's Agency), or they can be part of a diverse organization, such as the Development Director of Industrial Light and Magic.

The point is that trust is relative, and High Concept gives a calibrating foreground against which trusted agents can be evaluated.

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25 Role of Defense Sponsorship

[In this section we tie ManTech to the key improvement in the movie industry and make the general case for military sponsorship.]

25.1 ManTech, Movies and the Spruce Goose

[ManTech may be responsible for the key ideas of High Concept trust in the movie business.]

We've discussed the movie industry as exemplar of one type of AVE. In the first installment, Jeffersonian ideas about federation, and Quaker beliefs of trust and consensus support an AVE-based whaling industry. The meme gets established in case law and is carried via oil wildcatters to the movie industry, merging with Jewish ethics. Along the way, military investment plays a supporting, but not pivotal role. This example was published by the Agility Forum as well as on the web and captured widespread attention, though the meme idea appeared to be largely overlooked.

In the second chapter, the insights are as deep as the finding of the lightweight, case-law based system of trusted agents and agreements. We discovered two pieces of information: the first that the movie business provided a primary template for Japanese ideas of enterprise engineering we now call lean, that template empowered through military guidance.

The second is that the movie business has evolved since then to be more of a virtual enterprise, using what they call a packet-unit system of assembling frangible supply chains. To provide a nexus around which these supply chains can integrate, a highly evolved mission statement: High Concept, is often used. Also of note is the recognition of the importance of these new ideas of agility and VEs by some Japanese business visionaries.

That story may have an extraordinary final chapter which we were not able to verify in the time allotted. If true, it can add substantial value to the work that has been done. The story is that the original idea of forming opportunistic, agile supply chains was developed by the Department of War's *Manufacturing Practices Group* at Dayton, Ohio (precursor to Air Force ManTech). It was done for the shipbuilding industry during World War II, in an attempt to create an instant additional capability where none existed before.

This was during a period when the head of General Motors, acting as an army general, had gathered the Allies' best industrial thinkers at (what is now) Wright-Patterson Air Force Base, which as in WWI was the management center for war production. Some of these thinkers from the maverick Howard Hughes' company developed the idea to support the making of tens of thousands of *Spruce Gooses*, monster wooden airplanes designed to replace submarine-prone steel and concrete freighters. For uninteresting reasons, the war department fought the idea of the product (while supporting the refinement of the process).

So after the war, Hughes turned again to making movies, installing these same process innovators as heads of that business. Though Hughes' films were usually second rate, his packet-unit production system kept them profitable, providing a

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mature alternative to vertical integration which everyone in the industry had adopted by the 70s.

The story is believable because of the known legacy of defense sponsorship for novel business and manufacturing practices, including soft issues. This we briefly survey below.

The work on which we report in this document is sponsored by the U. S. Department of Defense. We believe that agility is a good idea, though not an entirely new one. After all, businesses have been responding to change for centuries. So, why would it be necessary to supplement market forces with government sponsorship? Wouldn't underlying tools for agility appear as a matter of course?

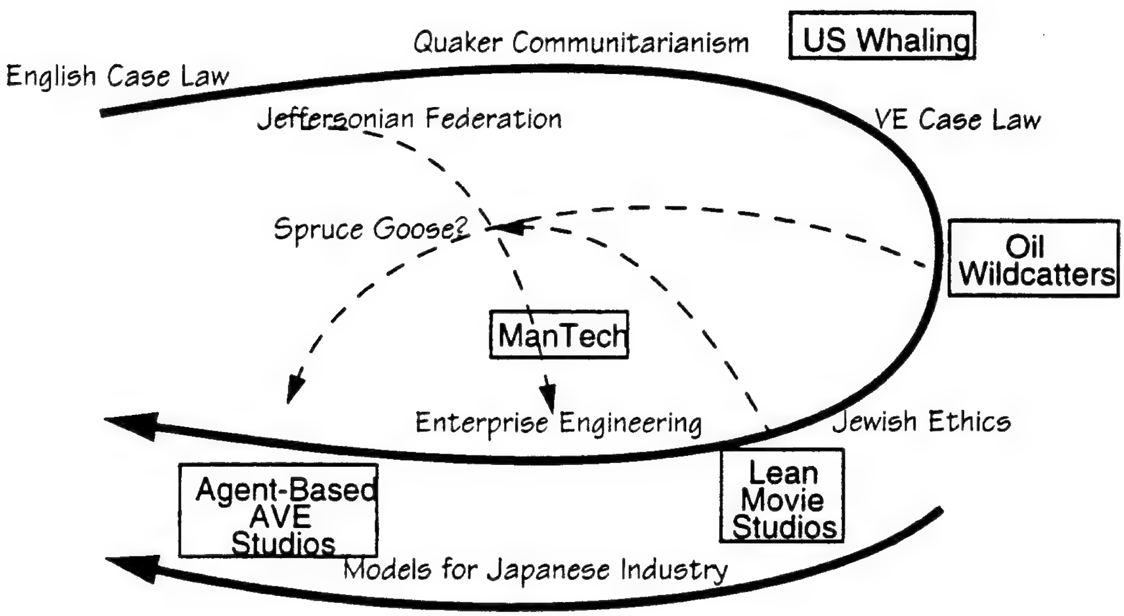

Figure 25-1:A Sweeping Case Study

25.2 Why Now?

[Agility is a key issue in defense, especially aerospace, readiness.]

The examples we've given are from the past. What has changed now to make agility of more imminent concern to managers? The dynamic of interest is the ratio of the rate of change that gracefully, spontaneously occurs in the business organization, compared to the rate of change of the environment. As the latter grows, the need for agility increases.

The ability of organizations to change, generally, is not remarkably better than in the past. And for the kinds of products that are increasingly of interest--high value-added technology-based products--it could be argued that change becomes much more difficult. Many of today's organizations are larger; new products require more communication among different disciplines and functions; and each

discipline's tools and methods are becoming more mature, and often less amenable to change.

But the rate of change in the environment is growing to an ever-increasing speed. The technology that goes into products, and that which goes into the processes to make them, is changing to an increasing extent. Competition has increased as we have become more of a world market. The customer is becoming more demanding, more educated, and more fickle. And finally, the rate at which the investment community re-evaluates its position has increased.

All of a sudden, the need for agility is no longer a matter of a few situations. The majority of enterprises in many business sectors need greatly to increase the ability to change, simply as a matter of survival. Soft issues are central to the problem domain.

25.3 Why Government Support?

[The only way agility tools will hit the general supply chain is through third party (government) intervention.]

The situation has changed from one in which agility was only occasionally important, to one where it is critical. This has happened fast, much faster than the support market (tools and technologies) has been able to respond. The support market, consisting of academic theorists, tool suppliers, and consultant practitioners, is what businesses depend upon to develop and support new business practices and underlying technology.

This support infrastructure is itself un-agile and has not been able to respond with adequate agility tools.

The situation is a natural for government research attention which traditionally works in areas which market forces will not address. Especially appropriate would be investment in the underlying scientific and engineering principles upon which tools and techniques can be created. And this is precisely the area in which we are working. This government investment is intended to help accelerate the development of market-funded tools.

What would happen if the government investment in agility were not made? We believe that various large companies would develop some agility tools anyway, as a matter of survival. But because those tools would comprise a competitive advantage, they would keep them for themselves, keep them closed, off the general market.

Since the resources of such companies will be committed for internal tools, this will starve the *open* market of the majority investment and customer base it will need to reach critical mass. AVE infrastructure tools and techniques will not appear in the market. Therefore, small companies would not be able to participate in AVEs unless they were under the sponsorship of bigger firms, a most undesirable situation.

25.4 Necessity of Government Investment

[Agility is one of several key infrastructure capabilities that are in the national interest.]

There are copious examples of this phenomenon in both business practices and technology, in pension funding, in telephone infrastructure, and in railroad technology. In all cases, the trend was toward *closed* solutions, and the government gently intervened. Today, we can hardly imagine the business world without openness in these areas.

An example of a good case for government investment is the original plan for SEMATECH. The U. S. had gone from being the major supplier of semiconductors in the world, to about 25% and falling.Japanese firms were taking much of the business. The *keidanran* was the main Japanese strategist.

The reasons were in large part because of the high cost of forming a large integrated enterprise from a diverse supplier base. The primary business of semiconductor firms is not the manufacture of silicon chips, but the manufacture of semiconductor manufacturing facilities, or fabs. These fabs cost on the order of a billion dollars each today, with the cost escalating drastically.

The useful life of a fab is alarmingly short, less than a decade, at which point essentially everything original is obsolete. Everything in the fab is provided by other parties, thousands of them, and every fab is different, markedly so, from its predecessor. The business game here is to integrate these thousands of partners quickly and efficiently into a high-yield integrated whole. Profitability is wholly a product of timeliness and elimination of waste.

Japanese manufacturers were able to excel because their monolithic, vertically-integrated keiretsu were able to gather and lock in the majority of suppliers and dictate integration standards to the remainder to a single operation. It's a crude integration model, which results in less innovation, but greater agility in the sense of quickly and cheaply creating a new fab.

In the U. S. the best suppliers innovated constantly, and they sold to all comers. But since each customer had different integration strategies, substantial energy over time was spend both on the supplier and prime side in integrating instead of innovating. It was an un-agile system, resulting in fabs which were not effective *learning* organizations. This is at root a *soft* problem.

SEMATECH (SEmiconductor MAnufacturing TECHnology) was formed to address this problem. Industry and the Department of Defense *each* kicked in what so far is a billion dollars to address the problem of creating an enterprise integration strategy that increased agility, allowing federation of processes and equipment from an increasingly innovative, competitive supplier base.

The U. S. response was one which leveraged the U. S. way of doing business, relying on agility through market forces (though the formation of the consortium was before the term became used in this context). Industrial partners include IBM, AT&T, Intel, Digital as well as other high tech giants, and the idea was to address collectively what these giants individually could not, even with massive and otherwise effective research efforts.

The Defense involvement was keyed toward protecting the domestic supply of a key component of weapon systems; this threat was underscored by the publication in Japan of *The Japan that Can Say No* coauthored incidentally by Morita. That

book described a Japan which controlled the source of technology for U. S. weapons in such a way that U. S. access could be denied.

The case for Defense investment and collective focus on agile infrastructure was clear and uniquely American. The early progress toward that agenda at SEMATECH forms the basis of this metrics project.

25.5 Example of a Bad Investment

[But infrastructure investments need constant, diligent management.]

As it happened, for a variety of reasons not important here, SEMATECH changed its focus from the agile enterprise integration problem to more mundane and simpler efforts in standards and preserving the supplier base through subsidy.

The idea of an innovative, agile domestic supplier base driven by, and fed by, free market forces has been abandoned. The semiconductor firms (to whom national defense is not a business concern), were forced into the Japanese camp. Today, each major U. S. company has tight, multiple relationships with former threatening Japanese competitors. The idea of a domestically-based strategic industry has been lost. Agility at the basic level is no longer on the agenda, yet the taxpayer investment has doubled.

25.6 Why the Advanced Research Projects Agency?

[ARPA has always been the driver for high risk/high reward infrastructure technologies.]

This agency, over 35 years old, alternates between being called the DARPA and the Advanced Research Projects Agency (ARPA), depending on congressional guidance. It is an agency of the Department of Defense, chartered with being the premier center for *high risk, high payoff* projects for defense needs. DARPA is well known for its many innovations in the area of basic information science, with a focus on precompetitive infrastructure.

DARPA has also dabbled in dual-use and manufacturing technologies, with mixed results. (DARPA sponsors SEMATECH.) We believe that the problems of agility, at least the ones described here, are matters of precompetitive infrastructure, instead of being manufacturing issues per se. As long as we adhere to the former, we are rooted in DARPA's traditional charter and proven strengths. In this area, they are arguably the premier agency worldwide in understanding and addressing fundamental issues.

DARPA sponsors the effort in agility which includes the metrics project.

25.7 Why Air Force ManTech?

[Air Force ManTech has a deep legacy in manufacturing infrastructure generally, and agility issues specifically.]

The *Manufacturing Technology Directorate* (ManTech) in Dayton, Ohio is less well known to the general public, but they have in many ways an even more interesting history. ManTech is chartered with insuring that the domestic Aerospace Defense Industrial Base has the most modern underlying technologies.

ManTech's legacy is truly impressive. Their predecessor organization was created in 1917, shortly after the outbreak of World War I. Although the U. S. had developed the first practical airplanes, the domestic defense establishment had ignored them. The U. S. had 23 aircraft at the outbreak of WWI, while the adversaries had over 500.

An organization was set up to manage the production of all allied aircraft together with the required infrastructure. This has to be the mother of all virtual enterprises, involving the coordination of international plants to build a capability which for practical purposes did not exist at all.

Within eighteen months, nearly 30,000 aircraft had been produced! What makes this feat so much more amazing is that the landing fields, logistics, repair, and training were created from a dead stop. Often, this work included massive projects in physical infrastructure for host cities--sewage, roads and the like.

One thing that made this possible was the collaborative transfer of information among partners. The most popular plane, the DH-4, was of British design, but the engine was designed in France and the armaments in the U. S. The coordination of information on design, manufacturing, and support from diverse sources under mostly local control required a new science of management. So they created this new management science, termed *systems engineering*. Our AVE requirements for new insights in management continue very much in this tradition.

After the war, Europe's military kept their defense plants under government control. We did not. Even then, Congress, without having an *industrial policy* per se, believed that defense strength was linked to a free-market based industrial base. The Dayton center, renamed Manufacturing Methods, was chartered to assure that the best underlying technologies, especially in enterprise practices, were employed in this industrial base.

Even at that time, there was a recognition that in order to have a strong defense industrial base, complementary commercial industries needed to be robust. Since there was no real market for aircraft, Dayton helped create one.

Dayton, therefore, engaged in three pilot projects. First, they heavily promoted *airmail*, creating customer demand for this service. Second, they developed the idea of regularly scheduled passenger service, as was already customary with rail service. But investors weren't biting. So they operated, as a demonstration, the world's first regular air passenger service: from Dayton to Washington, to Langley, Virginia, and back. (Langley was the nation's aerodynamic research center, later birthplace of NASA as it migrated out of DARPA.) The success of this venture convinced investors and spawned today's airlines.

Finally, they created an annual showcase so aircraft manufacturers could competitively display their latest innovations. This, in combination with a secure customer base, ensured technical progress for decades and served to create an industry culture. The event, much reinvented, still continues today as the Dayton Air Show, and its popular successors continue in other cities.

So, although our Army Air Corp's defense posture was poor at the beginning of WW II, Dayton was once again able to spin up a VE-based global manufacturing en-

terprise. The numbers here are equally impressive in scale (about 100,000 aircraft domestically, about twice that worldwide), but in this case there was a pre-existing base. Notably, the enterprise was less hierarchically centralized than one would imagine and depended heavily on peer-to-peer agile collaboration.

To maintain a strong base in postwar precompetitive infrastructure, Dayton played a leadership role in developing the underlying technologies for numerical control of machine tools, Computer Integrated Manufacturing (CIM), enterprise integration, and currently the Lean Aircraft Initiative. All of the predecessor work was conducted under either their or DARPA's sponsorship, usually both.

ManTech manages the effort reported herein, the AVE Metrics project.

Part 3, Soft Modeling

26 The Soft Modeling/Soft Mathematics Problem Stated

[Our beginning of an agenda of soft math needs to be continued. The agenda is outlined in this section.]

The soft part of the problem has several dimensions:

- The laws of Cartesian logic, on which current modeling is based are just simply inadequate to model dynamics of the social and cultural infrastructure. This is widely recognized [DEVL97], and there is now almost a stampede to explain the collapse of artificial intelligence in these terms. At the same time, the key role that those social and cultural effects play cannot be ignored.

But it is also true that:

- We need to have a model of the *threat* to the system, the behavior to which we are responding. It's not widely recognized that this is necessary, since most modeling is done in a static context, where external behavior can be essentially defined as boundary conditions. But dynamic modeling requires a specific model of the dynamic environment.

  But agility is by definition the ability to respond to *unexpected* change. How can one model behavior that by definition cannot be modeled? This requires soft modeling.

- The kinds of enterprises that are of interest are huge, complex and wildly diverse. We seek to understand agility which is driven by a very few factors, but which is a system-level phenomenon. Conventional techniques would demand that most of the system be modeled, but that is unrealistic for us. We've devised a trick to decompose types of dynamics via infrastructures that gets around this problem temporarily.

  But we lose the ability to get a handle on important system-level agility dynamics such as second order agility. A soft modeling ability is needed, to allow us to capture important features of the *context* of the enterprise, zooming in and out as required.

There are also probably families of novel analysis that soft mathematics could support. Trust is an example of one such family.

26.1 Three Possible Approaches

[We examined conventional social science, a new trend in epidemiology, and Situation Theory. The first is inadequate.]

The metrics are upstream metric). This means that we must have a formal model of the real processes at work. We then find the few features in those processes that affect agility and derive the information we need. This is an entirely different process than mere benchmarking, which asks questions only about the current state of the enterprise. We measure *capability*, so we need access to actual processes.

The first stage of the metrics is in the domain where we have explicit descriptions of the processes already extant. We have models, or can easily create models of workflow processes, business processes, and contracts and regulations. We are

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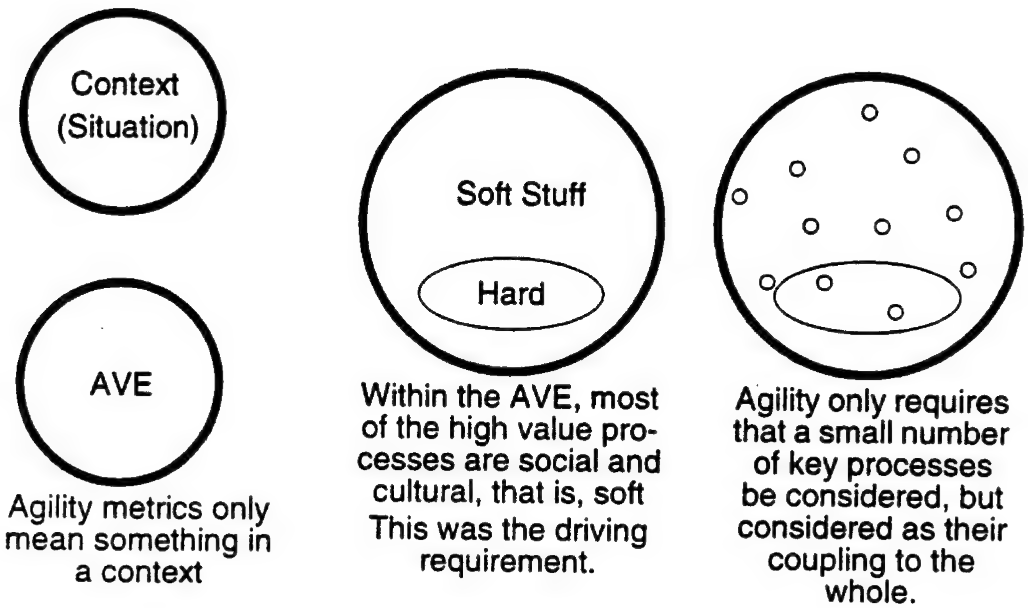

Figure 26-1:Three Needs for Softness

not so blessed in the cultural/social domain. The activities here are complex, implicit, and not well understood.

To make matters worse, there is controversy about how best to characterize what can be made explicit about these processes. A first order of work for us in the social/cultural context was to decide which one of the competing paradigms has value for us. The three paradigms are: ordinary social science, an epidemiology-based view, and situation theory. We have chosen the latter.

The default is *social science*, which we chose not to follow, was to pursue the conventional approach based on sociology, psychology, and anthropology. It's a robust area of work that has produced most of the existing insights we have into the organizational dynamics of VEs.

The approach used is reasonable. Coarsely characterized, it consists of large numbers of observations, from which theories are created and then tested by experiment--more or less, the scientific method. But these theories are theories of behavior, and not of the underlying physics.

For example, one would look at successful enterprises and notice that they tend to have a more *empowered* workforce. Since the correlation is high, one would theorize that such empowerment causes (or contributes to) success. The correlation is essentially a statistical one, which does not provide a well-understood model of exactly what is going on in a real causal sense: for instance, what varieties of empowerment change the organization in what respects to result (perhaps through many chained processes) in what particular kinds of success.

Much of the work in agility--and indeed also in lean and other management approaches--is of this anecdotal correlation type. That certainly has value for many uses, but not for our target use: high confidence metrics that can be used to *engineer* the VE for agility. In order to engineer something, you have to know how it works.

An analogy: for years, a connection between aluminum in the brain and Alzheimer's disease has been clear from a statistically correlated perspective. The correlation is clear, but since we do not understand the mechanism involved, we cannot say, even tentatively, for example, that people should stop drinking soda from aluminum cans. Such a temptation is great, but we simply do not yet understand the underlying mechanics sufficiently to engineer a response.

Medical literature is full of observations like this, which often give rise to superficial or speculative arguments about the validity of the statistical correlation: Does proximity to power lines cause cancer in Swedish schoolchildren? Does eating yogurt cause breast cancer? A recent study actually, incorrectly as it turned out, suggested this.

Even in cases where the correlation is clearly causal--smoking and lung cancer or aspirin and headache abatement--the underlying laws are what really offer the most potential.

This is important in the present context because agility is a whole new animal. The temptation is to revert back to conventional actions--flat, empowered organizations, lean work-in-progress, reduced, prequalified supplier base--and somehow to make a correlation between all that and agility.

But our case base in the context of agility is too small and too poorly understood to make a smoking-to-cancer causal link. Our understanding of how social and cultural dynamics work, even outside the context of agility, is poor. Furthermore, agility involves such a range of novelty that part of the nature of agility will always be, by definition, outside the available case base. But this could change.

So while we believe ordinary, conventional soft, social science contributes much, including indicators for further examination, we simply cannot use it as a basis for metrics. Statistical correlations without a formal model of the processes is insufficient.

26.2 Epidemiology and the Organizational Imperative

[There is an interesting, well funded trend in epidemiology, but it misses satisfying our rigorous criteria.]

Much of *epidemiology* follows the same model we just discussed. But epidemiology is the study of the *cause* as well as the spread of disease. It's a prospective science. So this requires use of statistics as an indicator of symptoms, but also indicates a need to dig deeper.

What attracted us to look at epidemiology in the first place was the introduction of social modeling into epidemiology from its origins in the days of Yellow Fever and Malaria. Researchers need to model the dynamics of the vector of the disease at the process level. For instance, they would take into account how fast mosqui-

toes breed, how far they fly, what mechanism attracts them to humans (which will involve other models of wind and what foods the people eat), and so, on into quite a bit of detail. (Incidentally, this *Yellow Fever* case study which corresponds to the building of the Panama Canal by the French and then the U. S. led to the French/British cultural meme insight).

But the important observation for us is that they must also model the social actions that promote or fight the spread of the disease. So they might model the degree of corruption or laziness of mosquito prevention inspectors, or the tendency of the local population to cooperate and learn certain preventive measures. Such factors were key to modeling Yellow Fever in Panama, and social factors are certainly relevant to modeling the dynamics of AIDS.

So we find here several attractive ideas, whose effects are amplified by the very large research budget of the National Institutes of Health spent on such modeling, compared to the relative paucity of manufacturing and commerce systems. One of these ideas is the deliberate mixing of models that are deterministic with those that are statistical.

In fact, the discipline seems to be pushing the limits of conventional statistical analysis to include several layers: the layer, for instance, that captures the likelihood of a person being in a high mosquito-breeding area, which is empirically determined, and the likelihood that this person has learned how to avoid getting bitten, an approach which combines some mechanisms with probabilities.

Another compelling idea from epidemiology is the inclusion into the vector of consciousness as a *collective*, and acting as an intelligent agent. Thus, the collection of malarial parasites does what it has to do to ensure its survival and spread, actions such as preserving the hosts and inducing sweating, which attracts more mosquitoes. It's a particularly powerful idea when one wants to consider how the organization learns; in this case, it would be how agility agents or memes evolve to its advantage in response to change.

When the idea is extended to *social action*, it generates particular insights. So, instead of just understanding an organization as an entity, we could understand particular ideas and other phenomena as entities themselves. An idea, for instance, the idea of guaranteed job security, takes on a life of its own, adapting in how it manifests and is handled by its hosts, in order to survive.

We mentioned something of this sort in the whaling example. When the industry spawned the petroleum business, certain key ideas had to adapt in order to survive. We noted that one suggestion was that these ideas chose Rockefeller, instead of the conventional view, that a great man shaped the industry after his own ideas.

The project's advisors, the AVE Focus Group, found this way of thinking to be useful for generating some insights and worthy of exploration and development. But we felt that the whole way of thinking strays too far away from managers' needs to generate some model science worth leveraging for the project. We instead invested in *Situation Theory*.

27 Situation Theory

[Situation Theory is introduced in this section.]

We have chosen, instead, to develop the ideas of *Situation Theory* as a basis for the modeling science for our metrics, the version of those metrics that extends the scope into social and cultural phenomenon.

Situation Theory is based on a few powerful ideas. A popular exposition of Situation Theory can be found in [DEVL91]with technical details in[BARW88]. One major idea on which Situation Theory is based is to separate the structure of the base case, the object phenomenon (often based in the real world), from the analytical domain in which it is analyzed.

For example, two well-acquainted machinists having a conversation about their work make certain presumptions for economy and conciseness. A non-machinist observer happening upon the scene might have trouble understanding what they say. Some aspects of this particular *situation* developed over the long term, coming from special machinist terms they use, as well as from conversational conventions based on their long association together, and some aspects are temporary, referring to what just happened before the observer arrived.

The idea here is to use a different set of rules and logic in characterizing the implicit meaning, that the observer missed, from the rules used in the conversation. The latter constitutes the *situation* in which the conversation was being held.

It seems logical that we distinguish between these two. It's not as if we're making the distinction between the discipline of machining and listening, but of listening circumspectly and *thinking* circumspectly about listening. The former is to some extent a result of fixed laws of physics and psychology, while the latter is not and is theoretically open to a wider range of abstract mathematical tools. However, the temptation to carry basic axiomatic content from the former to the latter is great.

Situation Theory makes clear the distinction between the two, by enforcing the view of a situation as a context for every action by an agent. This view of the agent is consistent with our use of it elsewhere); an agent is a discrete, self-aware entity with the power to influence other agents. The context encompasses of a number of aspects, some of which (like types and relations) have formal meaning only in the analytical domain.

27.1 Situation Theory in Linguistics

[The theory originated in the study of language and communication.]

Situation Theory emerged about 15 years ago in response to a set of problems in linguistics: how best to build a formal model of information to describe communication. An agent, then, will extract information from the environment, much of which was not communicated in any explicit language, but which, nonetheless, was understood nonetheless as if it had been communicated. That agent may then communicate to another agent some information, conveyed by conventional lan-

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guage, and some further information, conveyed by characterizing the inheritance of the situation.

So a study of language is a study of communication, and that in turn is a study in information. And a key component in the study of information is a formal approach to this idea of how the agent is situated. There has been a fair amount of work toward developing such a theory, with a predictably formal, specific, and sometimes abstruse collection of concepts and terms.

Individuals, relations, *spatial* placement, temporal placement, situations, types, and parameters are the stuff of Situation Theory. These factors are used in developing ideas about how an entity *individuates*, which sets certain characteristics about the potential for information transfer. The unit which is transferred is known as an infon.

One can already see, we hope, that Situation Theory goes far in clearing the slate and building a new basis for information about information, while being careful to inherit few of the mathematical assumptions which govern the milieu of the source information.

27.2 Ontology

[One major result has spun out of the theoretical work.]

The manufacturing enterprise is typical of many human enterprises in that its foundation resides in communication, information transfer. It is atypical of much human endeavor because we try to organize, engineer, and optimize the enterprise toward specific goals. Therefore, we have always had two, often overlapping, classes of people in the enterprise, those who do the work and those who try to understand and manage the work.

The primary tool of the second group is the *model*, broadly used here to mean a representation of what goes on. Modern enterprises, at least many interesting ones, use a large number of models and their associated methods to look at the enterprise's parts, viewed a number of different ways. So, much of the research currently conducted is oriented toward understanding, extending, and refining the art of modeling.

A key issue now being addressed, by Department of Defense (ManTech and DARPA) sponsored model researchers and others, is the issue of *ontology*. It's concerned with the formal specification of the elements of the model, so is very much in the scope addressed by ST. It comes as no surprise that the manufacturing modeling community is beginning to find Situation Theory particularly useful in creating enterprise ontologies.

Here's a simple explanation of what an ontology is: suppose you had two people that had similar backgrounds and they wanted to talk. Well, they'd have little trouble communicating. But suppose they both spoke the same language but came from radically different cultural and religious perspectives. The *basic worlds* that they live in could be so different that they could have little meaningful conversation, one could imagine.

But suppose you introduced a third person, a translator; not a language translator since they both speak the same language, but a *concept* translator.

> "When he says *here* (or *causes* or *seems* or *loves*, for example), what he means in your terms is..."

An ontology is a statement of all such relevant terms and mechanics of a particular world such that someone who speaks the language of the ontology (usually simple logic) can understand events and descriptions of events in that world. It's easy to see that ontologies are a major need in artificial intelligence when two knowledge representation systems need to share knowledge. The business enterprise needs ontologies when many models are combined, translated or federated.

The one solid practical result of Situation Theory to date is as a formal basis for knowledge representation ontologies where the difference between the systems is known and implicit. It has only experimentally been extended into the areas where the differences are not well explicated and the difference in worldviews is cultural [DR96].

Part 3. Soft Modeling

28 A Situation Theory Primer

[We begin an elementary overview of Situation Theory for our purposes.]

This section gives a brief, simple overview of Situation Theory *for the purposes of BAST*. More complete introductions are in [DR96] [DEVL91] [BARW88].

Situation Theory is novel in that it introduces a notion of *situation* as a *first class object* into equations that behave as logical statements. The trick is that a situation is a largely unknown blob of facts, in other words it is a soft object, one whose internals haven't been made explicit. These statements are usually of the form:

$S \models \sigma_1, \sigma_2,...$

or

S ⊨ <the specification of an infon>,...

where S on the left stands here for a situation, and the items on the right, which can be numerous, are some facts, pieces of information about the situation which are known as *infons*. The symbol that looks like an equals sign with a vertical line, adopted from Tarski, means *supported by*, or more specifically that the fact on the right is true in the situation on the left.

So the equation means that the situation S, which may be your situation is supported by the infons on the right, which might be true statements about the weather outside your window. We don't know much about your situation at the moment, but we do know a few things at least about its weather. We've made some *hard*, explicit statements on the right about the dominantly *soft* thing on the left.

28.1 Infons

[Infons are statements of fact, the hard stuff.]

The items on the right are *infons*, statements of fact. Infons articulate things about situations, in fact are the only way to articulate hard things about situations, so it's no surprise that they have a carefully designed internal structure. If the infon is in its usual form of a collection of items which states the fact, the form is as shown. The first item is a characterizer, a *name* for the fact, describing the action or characteristic involved. This is followed by one or more variables pertaining to the infon (more about those later), and the last entry is a truth value of 1 or 0.

S ⊨ <<(a relation), (a number of things about the relation), (a "truth" value)>>

S ⊨ <<speaks, HTG, [here], [now], 1>> has Ted speaking now

S ⊨ <<sits, HTG, [here], [now], 0>> has Ted not sitting now

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If the truth value is one the positive state is meant; this is the straightforward meaning of the fact is *true* in the situation. But as informative is the *negation*, when

the value is zero: it is true in the situation that the fact is not supported. (Another form of negation is in the *supports* relationship. In this case, the situation does not support the fact denoted by the infon, not the same as infon negation).

T $\models$ <<freezes, [August], 0>>This infon supports the situation in Tustin, CA
P $\models$ <<freezes, [August], 1>>This infon supports the situation in Perth
P $\not\models$ <<freezes, [August], 0>>This infon does not support the situation in Perth

The truth values support logical operations over infons, providing the basis for importing all sorts of existing logical tools to reason about situations.

The internal entities denote temporal and spatial locations, individuals, parameters (meaning indeterminants), and other situations. Also in here are *types* which we discuss below. Substantial effort in defining these entities has rewarded workers with a clean, computable way of reasoning about situations and contexts. Indeed, the foundation for defining and managing ontologies comes from this area. For our purposes, it's not essential to describe these entities.

28.2 Types

[Types can be not over conventional (hard) items, but soft situations as well.]

Each of the objects in an infon can belong to a higher order type, usually abstracted. The *basic* types are abstracted from the entities we described as constituting and infon, but there are also situation types which have some different properties because of the softness of situations.

One can investigate what types of hard stuff characterizes and constrains situations; indeed, this is the primary tool we want to explore in engineering situations. (Of course, in the AVE context situation is used in its ordinary, simple meaning.) Since infons have a behavior as *information*, moving around and changing their environment, one can also develop a theory of types that reasons about the communication *channels* they follow.

All of this emerged later in the theory's life. It evolved from strongly *set theoretic* ideas of logic and has migrated into basic mechanics of information abstraction and aggregation which are better suited to category theory. Recognition of that fact, at least so far as our AVE interest is concerned was a result of BAST.

Part 3, Soft Modeling

29 Physics and Behavior for BAST96

[This section introduces the issues of the first Business Applications of Situation Theory workshop.]

This section touches on a few of the issues, desiderata, and possible foundations of this new *soft mathematics*. The requirements and insights come from a study of social and cultural dynamics within the design of highly opportunistic, flexible, temporary associations of individuals and small groups that come together to act as a coordinated unit, *Agile Virtual Enterprises*.

When working with a phenomenon, one needs to have sufficient knowledge about how it works. More information than the minimum that suffices may be irrelevant for a particular use. We can assume that any system has a *logic*, using the term in its broad sense to mean the understandable laws that drive its behavior. The logic of many natural systems is, presumably, bottomless: that is, the more we study the system, the more of its logic we find remains to be revealed. We can never fully understand the logic of many such systems.

What we have, instead, is *information* about the system's behavior. As the logic is better understood, more information becomes available to us. The scientific drive is to develop more insight about a system's logic. But it is the job of the engineer to work with the information at hand.

For instance, we still have no deep understanding about the physics of gravity, its *deep logic*; but we have a great deal of information about its *behavior*. That *information* is sufficiently useful to allow engineers to make reliable and precise predictions about how certain gravitational systems will behave in the future. Meanwhile, scientists pursue the graviton.

The *logic* of a social system's *physics* and the *information* we have about its *behavior* appear to have quite a complex relationship. The relationship is more complex--and knowledge about the behavior is more useful--than might be implied by dismissive characterizations of behavior as merely a more abstract or less accurate approximation of physics. (It could be that behavior doesn't get enough respect.) *Physics is to behavior as logic is to information*. If we can use certain information to ascertain some of its underlying logic, then we should be able to work with an appropriate array of behavior in order to understand at least some of its physics. This issue has become important to our present studies in agility. We want to be able to look at a system and evaluate how adaptable it is, how easily its actors can learn.

We have a promising technique (for measuring the adaptability of systems) that looks at representations of processes which we require to be representations of very basic behavior in the system, behavior that reveals basic logic about the system's physics. Then, some analysis about the logic of the representation (or metalogic about the behavior) tells us how adaptable the processes are likely to be. We could, then, better predict behavior.

But the approach depends on the behavior which is modeled revealing the system's physics. That the modeled behavior reveals logic is a workable assumption when the physics of the system is artificial (human-made). Business rules exhibit an *artificial* physics: the physics itself is defined by a set of explicit rules. We don't

ordinarily have to perform scientific experiments to discover who is the boss of whom or who has engineering responsibility for a product. Usually, such things are explicitly (and reliably) stated; the physics results from the information.

Contract laws and regulations form a domain that is less well-behaved than business rules. It is not as deterministic--reasonable people can disagree over responsibilities in peculiar situations. And what is true has the additional burden of being admissible within the system. But the physics of the domain still comes from explicitly-represented information.

We also look at physical processes, for instance, the scheduling and sequencing of processes to assemble a device. Here, the laws of nature bear, but for all practical purposes of this domain, they are fully known all the way down to a given base: Newtonian physics.

But a great many of the processes--it seems, the most important processes--that bear on an enterprise are human forces, social, and cultural interactions. In these domains, the relationship between physics and behavior, as well as the relationship between logic and information, becomes quite significant. In these social cases, there are scant engineering principles. Dealing in these domains so far has remained more an art than a science.

But many of us would like to make better decisions about enterprises, to make them better in terms of human sensibility. After all, if collaborating workers aren't really motivated to participate, the enterprise cannot possibly work optimally, Uninformed decisions can end up creating the sort of organizations we want to avoid: those which are brittle, unlikely to adapt, and unrewarding places to work.

29.1 Information Foreground and Background

[Situation Theory currently covers background information. We need it to handle the direct information of the communication in the same, soft manner.]

This problem is not trivial: namely, the application of mathematics to human interaction. It may be our foremost problem in re-examining the foundations of information science. Our subset of that grand challenge is whether we can come to a better understanding of information in these interactions to help enlighten us about their logic (or laws or mathematics or physics, if you prefer).

A decade of so ago, we took a giant step forward in addressing the problem. In simple systems, the information that is conveyed between two entities is entirely to be found in the *communication* between them. That has been largely the case in our relatively simple domains of business, legal, and physical processes. But in human communications, often, what is conveyed is mostly not explicitly found in the actual message.

Often, much is unconsciously assumed among the parties about the situation. Some of these assumptions are domain- or culture-specific: a *spanner* means one thing to a British mechanic, another to his or her American counterpart. Some are common knowledge: a cake can be put in a box, but not the other way around.

Some are implicit inferences, and some seem to be hardwired into the particular linguistic binding we undergo when young.

The advance in addressing these issues was provided by Situation Theory. S Situation Theory was enthusiastically embraced by linguists and cognitive scientists, and found immediate application in artificial intelligence (AI), a specific problem in knowledge representation. There, Situation Theory is applied to the problem of formally defining a domain or microdomain (for our purposes, other terms for *situation*) for each communication. Hence, each communication has a foreground (the information that is in the communication or message itself), and a background (information from the situation, which is communicated indirectly). The idea of an explicit representation of the background information into ontologies tidies that AI problem up nicely.

That solution was fine for that near-term problem, but it established a new hierarchy which has limited Situation Theory, a division into *foreground* and *background*. This division places Situation Theory as a kind of second-class mathematics in the context of collaboration, that of dealing with issues secondary to information and modeling. Situation Theory brings new thinking about the relationship of information to the logic and information, but it has been divorced from the primary communicative act.

It has been suggested that the assignment of Situation Theory to the background is a result of mere fashion in mathematics, for which there is no fundamental mathematical reason. If Situation Theory were applied in the foreground, rather than as a supplement to get more life out of a older approach, new insights can result.

29.2 BAST96

[The logistical details of the first workshop.]

Keith Devlin and Duska Rosenberg [DR96] have applied Situation Theory with some success to understand primary communication in social contexts, and we took this as the starting point for the First Business Applications of Situation Theory (BAST) workshop. Devlin goes further in a recent book [DEVL97]: there is a need for a new approach for understanding the logic of human expression and communication. Situation Theory provides a first step toward this *soft mathematics*.

BAST was concerned with the soft mathematics agenda generally. The means of approaching that agenda was to examine the social dimensions of collaboration in business environments and to explore the applicability of Situation Theory to impart better understanding. Focusing on business applications makes the agenda real, and the potential for improved collaboration can serve as an impetus for continued work. We assumed that the best examples of this kind of collaboration are typical of essentially all collective human efforts.

BAST96 was cosponsored by the project and Steelcase, Inc. It was hosted by the Aerospace Agile Manufacturing Research Center of the Automation and Robotics

Research Center of the University of Texas at Arlington. And it was facilitated by the Industrial Technology Institute.

We brought together three communities:

- Mathematicians:
  - Keith Devlin, Stanford and St. Mary's
  - Denès Nagy, University of Tsukuba
  - Jeff Weeks, University Of Minnesota Geometry Center
  - Scott Baldridge, University of Michigan
- Social Scientists:
  - Duska Rosenberg, Brunel University
  - Brian Turner and Todd Cherkasky, Work and Technology Institute
  - Noshir Contractor, University of Illinois
  - Bill Hutchison, Behavior Systems
- Enlightened Implementors/Practitioners:
  - Ted Goranson, Sirius-Beta
  - Van Parunak, Industrial Technology Institute
  - Jamie Rogers and Youngmoon Leem, Automation and Robotics Research Institute
  - Chris Menzel, Knowledge Based Systems
  - Arthur Baskin, Robert Reinke and Rajaram Ganeshan, IMPACT Lab, USC

Figure 29-1:BAST96 Participants (Note Tee Shirts!)

The work plan was to have the mathematicians and social scientists examine the prior work of Devlin and Rosenberg, explore new directions in the context of two inter-related, focused problems, with the goal of both indicating viable implementation strategies, and defining a research agenda. All of the attendees had been chosen in part because of their ability to deal with complex, interdisciplinary is-

sues. Although the topic is essentially mathematical, we hope to speak a commonly-understandable interdisciplinary *Esperanto*.

We planned to have three products of BAST.

- A general research agenda to extend Situation Theory into the business domain, specifically as a framework for modeling tacit dynamics.
- A specific approach to the business problem posed by Steelcase. This problem (and solution) are not reported here, except in the briefest of terms: The problem involved two elements:
    - how to calculate the *learning path* which an *organization* needs to take when presented with the need for change. In this, the problem was more ambitious than that posed by Sirius-Beta. We only wanted to understand (measure) where Steelcase wanted also to calculate the action. No progress was made on the action half of the problem, only the analysis half shared by Sirius-Beta.
    - what would constitute a graphic tool for such techniques as the *assessment center method* (a technique for psychologically measuring and testing management skills). A graphic tool would serve the same purpose for the assessment center that the fishbone diagram serves for the quality movement.
- A specific approach to the problem posed by Sirius-Beta on behalf of the project. This problem statement is outlined below as it was presented:

29.3 Problem: Soft Metrics for the Agile Virtual Enterprise

[A synopsized statement of the primary problem posed at the workshop.]

The Virtual Enterprise is an interesting type of collaboration. We use the term *enterprise* to mean that in aggregate there is a collective goal, which may not be apparent by examining any single constituent. We include special enterprises like government, whose goals broadly are the welfare of its citizens, as well as the typical business enterprise, whose goals are relatively more near-term and more easily measured. (DARPA') special case is the amalgamation of these goals in the defense industry.)

The *Virtual Enterprise* is one whose constituents are collected opportunistically when a need appears and whose only bond is the collective goal. In this case, collaboration is required not only to *do the work*, but also to form the various special infrastructure) that permit it to act as a coordinated entity. The most interesting and useful virtual enterprises are ones without preconceptions as to the granularity of its members, be they individuals or large enterprises themselves.

An *Agile Virtual Enterprise* (AVE) is one that can respond to unexpected change, not only when forming to address an unexpected opportunity (or disaster), but whose inter-unit couplings are sufficiently dynamic to allow it to reconfigure on the fly when that opportunity unexpectedly changes and to end when the oppor-

tunity wanes. All this adds further, even more challenging dimensions to the need for collaboration.

DARPA and NSF are sponsoring a number of research projects under the rubric of agility, collectively totaling over $100M. The underlying need is to be able to engineer agile systems in the enterprise itself as well as to provide ready tools and infrastructure. As with engineering of all systems, the formal basis begins with an understanding of the phenomena of agile communicative couplings and how to characterize them.

The Metrics project is focused on this root problem. In the past year, some substantial progress has been made in understanding the nature of agility in this context and also what it would take to measure it. What we do is straightforward. Agility results from the dynamic coupling of diverse, intelligent components in a system; we identify those couplings in the infrastructures of interest, understand the transactions involved in those couplings, and abstract out measurements from those transactions.

In particular, we have a method of decomposing the enterprise into communicative acts that can be used with any number of common modeling techniques; it constrains *what* the model captures. The approach constrains the model fragment under scrutiny to be completely within AVE processes and to be within certain infrastructures. An example of a process may be: *Having defined matching capabilities and determined a fit in goals, the parties commit to the AVE.*

An example of an infrastructure could be: *contracts infrastructure for quality assurance provisions*. There would be processes for many of the cells in a process-to-infrastructure matrix; we have determined and validated the processes and infrastructures for generic cases.

The approach also constrains the *how* of these many model fragments, simply by requiring each element in the model to be no more nor less than a single one of a small vocabulary of simple communicative acts. The result is that all of these small models are normalized representations of couplings, transaction boundaries among the elements of the AVE. Because they are normalized, we can move beyond of the semantic meaning of the models and analyze their topology.

The topology of the transaction is the only characteristic that comes into play, since it fully captures the dynamics of the coupling among entities. We abstract out five features that form a sparse set of categories that capture this topology.

In the general case, these features might be placed into a category space, where one can conduct various analyses. Two mathematical ideas are used. The first is that the features (are made to) form regular, periodic concept lattices, which can be manipulated and transformed using an algebraic grammar built of symmetry primitives. This means that the complexity of the representation case remains constant as the situations become complex. Simulations of real-world, large enterprises that accomplish complex work become massively complex, so scaling is a key concern.

The second deals also with the topology of the category space into which we put these concepts. What we have are vector-like representations of concepts. By

manipulating the topology, we can cluster concepts--in this case, agility concepts--into bundles using robust analyses developed for computational fluid dynamics. This is important because we need a way to visualize results trends; in a real, complex enterprise, there's just too much going on to comprehend by looking at concepts individually.

At BAST, we had a symmetry expert whose international organization has a well thought out small project to test the idea of a representation space which is periodic. This project is an interdisciplinary taxonomy to be used to index scientific/scholarly papers for interdisciplinary work. We also had a topologist who has outlined (in the simplest way) how a clustering space might look with agility features.

These two techniques and the basis for abstracting dynamic categories have been demonstrated to have utility in a similar space in the intelligence community. The three previous paragraphs describe the general case for enterprise strategists, but there is a simple method for evaluating the five agility features locally for each model fragment. It involves a simple algorithm which converts the model into an act-oriented state diagram (a Dooley Graph). This technique can be used by a local middle manager.

If the outline above occasionally introduced unfamiliar topics all too tersely, don't worry. There only a few things that are most essential in the BAST context. One is that we are working hard to rely on tool paradigms which are mature, well-known, and widely used in businesses today: We can import any number of different modeling methods (mix and match), and we can feed analytical tools developed for business analysis, and we can leverage for business use many tools originally developed for engineering physical systems. Really powerful ideas, that can be used for any dynamic characteristics, not only agility.

29.3.1 The Difficulty for BAST

[How do we reason over situations with supersoft dynamics.]

The hitch is that we require, as input, models whose information carries the complete *logic* of the process. In other words, the way that the process actually works, its laws, indeed its essence, can be seen in the model. This is fine for artificial processes, ones created by man through fiat, for example: *who supervises whose work*. It also works well for physical processes whose physics is clear, for instance: the limited number of ways that certain parts can be assembled.

Overall, the metrics, the engineering, of agile systems, can currently be applied in the infrastructure we've called legal/explicit. This includes contracts and regulations, workflow, and business processes. Included as simple cases are the processes in the physical infrastructure dealing with logistics, transportation, scheduling and such, governed by space/time. This is because information in models of all of these processes can adequately capture the explicit *logic* of the process.

But what about social and cultural processes? All interesting AVEs will include major processes whose collaboration depends on these dynamics. Indeed, we've identified a Social/Cultural infrastructure which covers business culture, *commu-*

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nity cultures (including discipline- and sector-specific as well as community ethnic and national cultures), and social dynamics (the apparently *hardwired* psychology of group dynamics). These are processes we don't yet understand well. In some cases, we can model the behavior but without understanding the laws at work.

Without considering the social infrastructure, the metrics can still be useful, but in a limited way. With them, the technique is as revolutionary as the concept of AVEs. So the problem for the Metrics project is whether we can create models of social transactions that sufficiently reveal a *logic*. Can we capture implicit processes in a way that *appears* explicit in our normal space (or its Dooley Graph shortcut)? Or stated a third way: can Situation Theory be used to create a *foreground* model of a process, if we simply know some behavior of the context, the situation?

Is it feasible (meaning manageable, reliable, and inexpensive)? (One of our BAST implementors was a creator of business process modeling tools who, incidentally, is familiar with Situation Theory.)

Also, is the solution as open as the use to which it would be put? We'd like to think that one result of engineering of agile systems is to make a path to empower freedom of small teams and individuals as well as federating self-organizing innovation--concepts that leverage American strengths. It would be a problem if the use of Situation Theory for our problem required reliance on a single paradigm, some element with central ownership. That could centralize and institutionalize what we want to distribute. (Our BAST social scientist is concerned with the quality of the workplace as a strategy for high performance enterprises.) Clearly, explicit modeling of social processes presents several challenges.

29.4 Memes, Processes, Agents, Patterns

[A suggested approach could use an agent metaphor for actions of the context. Perhaps memetics is useful. Perhaps action patterns can be typed.]

Here we suggest some techniques for addressing the agility problem in BAST. Briefly stated, the problem is: How can we model those processes with predominantly social content in the same explicit way that we model *ordinary* processes? There are several researchers who add a social *context* to conventional models, in order to combine or exchange models from different contexts. Situation Theory provides a basis for that.

(Knowledge Based Systems Inc., represented at BAST, is probably the leading practitioner of this approach.)

But we'd like to do something else, something more direct. Clearly, we cannot do what we want if we pose the problem in the conventional way. The challenge has two parts. While we reach for novel ways to extend the thinking of Situation Theory to form a basis for a usable soft mathematics, we also have to invent a new way of posing the problem. Here, we address the latter part.

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29.4.1 The Problem

[The ideal would be to discern self-organizing dynamics, natural trends.]

At the highest level, the problem is that we want to be able to understand features (in the present case, the adaptability) of human collaborative processes. The goal is to be able both to understand the general principles which make for agility (in given contexts) and to be able to engineer specific enterprises in beneficial ways.

A less imaginative way to use such an understanding would have managers making many, small decisions about the agility of partners and employers according to a specific strategy. A more interesting strategy is applied at the infrastructure level, in unions, schools, and professional societies. In this case, we'd encourage behavior, skills, and other phenomena that tend to *self-organize* into agile organizations from the bottom up. We'll rely on this latter view in our search for novel statements of the problem.

(At root, these are workforce issues. The most advanced thinkers in this area are with the Work and Technology Institute, also represented at BAST.)

29.4.2 The Normal Way of Looking at the Problem

[Current methods in the theory keep intent on the left. This is a limitation.]

Let's start by looking at the conventional approach. In this scenario, you have an enterprise, in which decisions are made by managers. Such an enterprise operates under a strategy, conducting a number of activities to advance that strategy. These are the basics. In our view, the most interesting enterprises are composed of smaller enterprises, each with its own take on strategy and its own set of decisionmakers. This complicates things and makes it more difficult to understand how individual activities in disparate companies support the strategy of the partnership.

That's what we normally do--look at activities to see how well they serve the strategy. Such models are models of activities (or something essentially like them: processes, data flow, etc.). In order to carry information about how the model works in the larger context, innovative modelers use Situation Theory to add the information about the *coupling* of the enterprise and its strategies to the process. It works after a fashion to give the logic of how and why the activity supports the enterprise's goals, but it throws a lot of responsibility on Situation Theory, weight that can be overwhelming when the relationships are deep in the context, not readily apparent, soft, coming from social and cultural infrastructure.

We'll propose a new way of looking at the problem, as a suggestion for facilitating BAST discussion. This suggestion preserves the idea of the *who* (the enterprise), the *what* (the strategy), and the *how* (the activity), but gives a new perspective on each which spreads the mechanics of the logic into each component. At the same time, we hope to extend the applicability of the modeling to allow us directly to identify and understand the importance of social behavior, with a focus on behaviors that support learning (i. e., agile) systems.

29.4.3 A Slightly New Perspective

[Can we put intent on the right in a notion of action?]

We'll propose new candidates for each of the three elements (enterprise, strategy, and activity), then briefly discuss how this simplifies the problem and enhances the understanding of social dynamics. Finally, we'll take a shot at how this helps open a more direct way to use Situation Theory in modeling.

29.4.4 Process

[Action is needed because we can relate processes and process intent to actions. That notion of intent can include the intent to adapt processes.]

Work that we have reported elsewhere already has changed the definition of the how. Conventional organizations define these activities in terms of functions in the organization, such as marketing, design, shipping, etc. We thought this confused the structure of the enterprise with the work of the enterprise. So we devised a breakdown of what constituted the activities of interest.

A table or matrix resulted, which separated these two elements. Down the side, we recorded the activities that are conducted by a generic virtual enterprise. Along the top, we collected the infrastructures that needed to be created, managed, and disassembled. The entries of the matrix are the processes of a typical agile virtual enterprise (AVE).

We envision this matrix to be a useful, intuitive management tool for a number of purposes in beginning the metrics evaluation and identifying commonly beneficial processes. Incidentally, in management philosophies, such as lean manufacturing, such identification is easy; lean is defined as a collection of good practices that nearly always apply. Agility is different in two ways:

- Unlike lean manufacturing approaches, agile processes are *context-dependent*. What might constitute an agile capability in one type of change might not be agile in another and could actually take you in the wrong direction.
- Unlike the lean approach, with its checklist of independent and cumulative good practices, in agility the strength of each beneficial process acts on the behalf of others, interdependently. When we used our matrix to test known good cases of agility, we were surprised. All examples had only one or two very strong entries in the process cells; those strong entries mitigated the need for excellence in the others.

Since each of the cells is linked in a way to create an enterprise model, it should be possible (once each cell's metric has been calculated) to play with the matrix by increasing or decreasing one number and seeing the consequences in other cells. (An advanced notion of this is illustrated by a BAST attendee who has programmed a demo of a similar analysis of features derived from the cells.) Of course, before we could consider this, we need to have models in the *social* rows look and act in a way similar to those in cells where processes are more well-behaved.

The bottom line here for BAST is that in the method so far, we've already transformed the *how* of activity, which is usually defined as *function*, into process. And these processes are clearly segmented according to their underlying mechanics, whether explicit or implicit.

29.4.5 Agent

[An agent or action means something different in the social/cultural context.]

Conventionally, the unit which is considered as the agent or actor is the corporation, or in composite situations, the enterprise. In this view, there is a corporate body, and each component plays its role in a coordinated whole. Thinking and commitment comes from central organs, and the appropriate parts act accordingly. This is neither a useful nor realistic vision for the AVE. In order to be agile, all the parts have to be coupled in such a way that the coupling mechanism is dynamic, meaning that the organizing intelligence needs to be distributed somehow among the constituents. Moreover, in the real world, AVEs really do have distributed management in the component companies. An agile response may be to decouple from some partners and couple with others.

So we've turned the *what* on its head also. In conventional modeling, the *what* is the enterprise; for our agily coupled systems, the what is the fine-grained component, which has to act as an agent. Needless to say, these agents must exhibit some self-organizing behavior. (An expert in self-organizing systems was on hand and available at BAST).

Repositioning the performer as an agent who has self-organizing behavior is more fundamental than merely a change in perspective. Agents and enterprises both have capabilities which are easily modeled, but in the case of the conventionally-defined enterprise, the coupling occurs through a control structure; in the case of an agent-defined enterprise, the dynamic coupling occurs through a risk-reward structure.

Refiguring the modeling problem to show the logic of risk-reward coupling may be more manageable in the BAST context than looking at the dynamics of a socially- and culturally-influenced enterprise control system. In particular, it gives leverage in the definition of the how. This idea is pursued below.

We should make it clear that we are rethinking the modeling agenda only for the social infrastructure. It seems clear, at least intuitively, that all of the explicit/legal infrastructure dynamics depend on an enterprise-wide, explicitly supported control structure. It is only within the dynamics of the social/cultural infrastructure that we suggest change.

29.4.6 Meme

[We suggest memetics as a metaphoric framework for one special element of actions in societies.]

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Agent systems have been studied in some depth now; the basic environment is one in which the behavior is wholly a result of local decisions by the agents. Things get more difficult when one tries to engineer behavior of agents so that the aggre-

gation of local events produces predicable, desired behavior. It's as if one wants to emulate a system-wide control system by designing agents and their behavior carefully. An example of an application where this succeeds is in scheduling systems, where the applicable laws are physical, explicit, and logical.

In such cases, a key idea is genetic programming; an idea that relies heavily on a biological metaphor. The mechanism is that of the *selfish* gene, a concept developed to understand how systems evolve. The idea is that genes act selfishly to replicate themselves; from this particular perspective, humans (or other living beings) are regarded merely as part of a gene's strategy for replicating. In general, the more successful the system, the more successful the replication strategy.

This concept or observation has been extended with the idea of memes. Memes are self-replicating ideas or entities which can be seen as collections of information. Like genes, they can exist in stored form, for example in books; and like genes they act selfishly. Many social and cultural conventions can readily be seen as the evolving result of interacting memes; this parallels the way many characteristics of biological life have been characterized as the result of selfish interactions among genes. Incidentally, we side with the view that considers memes as a superset or superclass of genes, genes being limited to relatively slow evolution through biological replication. Both memes and genes consist of ideas or information and both appear to act opportunistically to survive.

Why consider such a thing a meme? Because we're getting value out of changing the perspective from *top-down* enterprise behavior to *bottom-up* agent behavior. Much of that bottom-up behavior can be understood in terms of memes. (One meme, the idea of fairness--a relatively modern concept--as it operates in collaborative work is among those being explored by Steelcase and the IMPACT Lab at USC, participants in BAST.)

We think there is value in looking at how memes enable agents to interact between themselves in order to further the desired processes. This idea of memes represents an inversion of the strategy of the enterprise. The enterprise's strategy, at least in the social arena, results from an aggregation of human transactions that serve highly local risk-reward systems. We believe that many of these risks and rewards can be seen in terms of memes: for instance: fairness, personal control, belonging, and expectation of appropriate status.

Engineering agile systems in the social context may mean either choosing the right meme mix (e.g., through selection of subcontractors), or better, cultivating the right memes among the players (e.g., by learning from collaborators to help determine what constitutes appropriate risk and reward). This view can give us a better insight into high performance work forces than conventional perspectives.

29.4.7 Relevance to BAST

[Can we action-like memes on the right hand of situation statements?]

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The concept of the meme was developed in order to illuminate certain large processes (such as the propagation of beliefs, rumors, standards, world-views,

etc.). We've adopted it to help shed light on another large process, namely, the enhancement of agile strategies in enterprises. One way to cast the agility problem at BAST is to describe it in terms of the relationship between the dynamics of a meme and the context of a change and the strategy to address that change.

Situation Theory includes two high-level concepts: a *situation*, which can be intuitively understood, and an infon. An infon is a unit of information. As a suggestion to start addressing the problem at BAST, we propose that we see as the domain of situations of interest the larger world of commerce which the enterprise serves, the specific conditions of change which require response, and the manifold components (agents and inter-relating control and risk-reward systems) that constitute the enterprise, as reflected in constraints of our infrastructures.

All information in the enterprise consists of infons. But some of those infons should be defined as persistent and active, and so provide a ready reserve, so to speak, of institutional capability to respond to change. We're not proposing an equivalence between infon and meme--they're of different genera--but I do think the use of the terms together narrows the gap between Situation Theory and the agility problem. (Persistent infons of action at least resemble the self-replicating ideas called memes.) Perhaps this idea can facilitate the BAST enterprise.

The beauty of this problem set appears in its sensitivity to the incremental evolution of Situation Theory. The ability to understand fully social collaborative interaction, much less improve it, has been practically negligible. And the costs of a lack of science, computed either socially or in conventional business terms, is enormous. Therefore any, even small, improvement means a lot.

Such was the challenge given to the BAST workshop in May of 1996.

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Part 3. Soft Modeling

30 Results of BAST96

[We report the relevant results so far as social/cultural metrics are concerned.]

30.1 Actons

[We proposed an action-based acton, in ways symmetric to infons.]

The primary atomic logical unit in Situation Theory is the infon. This is a result of the tradition which has as its goal support of *First Order Logic*, the primary unit of which is the *fact*. As it is, Situation Theory has well developed support of fact-based logics and models which are built on those logics.

But most of the useful models of the enterprise are based not on facts but on *actions*. Certainly this is true of the models from which our Dooley Graph-dependent approach depends. A reason for action models over fact models is that the most useful models are those that can be used both for analysis (as with our metrics) and for control of the enterprise. One can see a trend in manufacturing modeling away from IDEF1-like fact models to IDEF3 and 6-like action models.

So we proposed introducing a new entomological construct of *doing* to the existing one of *being*, with the new construct we termed an *acton*. An acton (which we denote with the Greek letter *alpha* where infons use a *sigma*) has the minimal following form: a set of preconditions, a set of postconditions and a *truth* value.

The pre- and postconditions concern what the states are before and after the action. These can be purely in terms of infons. But the intent is that infons and actons can co-exist, so the conditional phrases can be mixed. The acton's truth value is specifically devised to permit this sort of mixed mode inferencing, so it is similar to that of the infon. One value is that the situation supports the action, and the other of course that it does not.

There was some disagreement over what *supports* means. The majority felt that there are some deep issues surrounding the introduction of the notion of state into Situation Theoretic phrases, and the cleanest handling is that the situation is one in which the action both *can* happen and did.

A minority felt that the state issue is either not a problem, or is a manageable problem and held out for *supports* to mean only that the action could (for all we know) happen, but that it hasn't, or alternatively hasn't successfully happened. The argument for this is that the greatest power of actons comes when they can be considered as executable code, and especially when those pieces of code can be allowed to interact to discover emergent behavior.

Because prediction of successful action completion may depend on complete system-wide knowledge, and since by definition situations are never fully defined, successful completion cannot be assumed.

There was much discussion on this. It was left with the majority position as a working start. And it was posed as an issue for a BAST2, which will involve Situation Theorists who are known to have struggled with deep issues of state.

It's worth noting that the attempt is to introduce a *bicameral* nature into Situation Theory, facts and actions. This mirrors the approach which permits our metrics: the Dooley Graphs which combine the notion of (act-related) *states* and (fact-related) performatives. Such bicameral systems are widely believed to be essential for reflective systems, theoretical systems which can see and theorize about themselves.

Soft problems probably require reflective theoretical capability. This is because they are cognitive aids to understanding systems which, in the soft case, include cognitive dynamics. We'll revisit this below in making a more far-reaching proposal.

30.2 Three Kinds of Soft

[We differentiate between tacit information and the soft information which is our difficult problem.]

We discovered that there are several notions of *softness* in information which apply, whether fact or action based:

- *Tacit*: information which is not known, but which can be known with some effort. In other words, there is no theoretical barrier that prevents the *soft* from being made *hard*, explicit. This is the primary currency of Situation Theory generally, and the cutting edge in social softness deals with tacit contexts [DR96], which provided a starting point for BAST.
- *Ssoft* (Supersoft): information which is not hard (not explicitly and logically stated) and which has no existing logical framework to make it hard. For instance, there are no Maxwell's equations for group motivation. This is the target of the Metrics project, our Social/Cultural Infrastructure. In particular, we are interested in the component we call Community Cultures. At BAST, we broke this

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down into the areas shown.

	Communication and Collaboration	Equity and Status	Association and Support	Influence and Workflow
National, Regional, Ethnic				
Sexual, Racial, Religious				
Class, Trade, Corporate				
Other (Patriotic,...)				

Table 30-1: Ssoft Dynamics of Concern

Ssoft Plus: information for which there will *never* be capable of being made hard. Whether such a category exists and if so what discriminates it from Ssoft is not cogent to the present discussion. So we decided to not distinguish the two. However, in addressing the issues of state in BASTX it may become an issue. One can posit a state (however costly and far in the future) at which Ssoft information can be made hard: what Devlin and Rosenberg call *Zooming*. But if Ssoft+ exists, such states may not always exist. This possible irresolvability may be important in resolving the state controversy noted above.

30.3 Drop the Meme Baggage

[The suggestion for the meme metaphor was rejected as insufficiently rigorous.]

In the Project, we've found it useful to employ examples. Where those examples deal with Ssoft issues, the concept of memes has been useful as an expository device. And we included it in the preparatory problem statement for BAST. We felt that there is a class of acton which is not only capable of supporting situations, but also of modifying future states of those situations. These actons would promote or support some emergent or self-organizing behavior, and memetic ideas seemed to fit well.

However, during BAST we discovered the concept to be seriously lacking in the rigor required to further rigorous dialog.

- There is a spectrum of people working in the area [LYNC96] [BROD96], and these range from the serious to the pseudoscientific with a preponderance of the latter. Most troubling is that with the exception of specialized work on narrow areas [BLOO95]there is no single outstanding seminal, defining work.
- There are many cases where memetics has been positively used to help explain Ssoft dynamics, similar to our own use above. But in those cases, the application is retrospective meaning it sheds some light on what happened. No study exists which employs the true test of a scientific theory: to *predict*. Substantial discussion on <news://alt.memetics> has convinced us that this is because of some fatal missing capability in memetic thinking.

Therefore, BAST recommended that we drop the *meme* baggage, and find a better set of metaphors for serious investigation into Ssoft and Situation Theory.

We had already committed to the FIS96 (Foundations of Information Sciences) meeting to be held in Vienna a couple weeks after BAST. (In fact, we were on the program committee as well as that of another group (International Society for the Interdisciplinary Study of Symmetry) which included an FIS session.) The FIS members are specifically concerned with careful examination of self-organizing natural systems, and are interested in including the BAST agenda. They asked for a BAST contribution (for example [MARI96a]) and a BAST focus in the next FIS gathering.

Incidentally, the meme idea served us well as a place holder for a missing piece of our reinvented *Tool Food Chain*. One guiding roadmap of the Suppliers' Working Group was a food chain of dependencies. Change in how industry engineers itself is dependent on tools (such as those related to the metrics). But these are dependent on better tool building tools, such as the metrics. The canonical dependencies are:

- Change in how industry engineers its enterprises
- Enterprise engineering tools and technologies
- Tools to build tools
- Infrastructure
- Conceptual tools
- Applied math
- Pure math

The following figure shows that food chain in the center, the current defaults at the top and our alternatives at the bottom.

30.4 Constraint Grammars

[We need to look at the special needs for soft constraint grammars.]

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One of the useful applications of Situation Theory is the ability to create and reason about Types of situations. In the social situation context, Rosenberg [DR96]

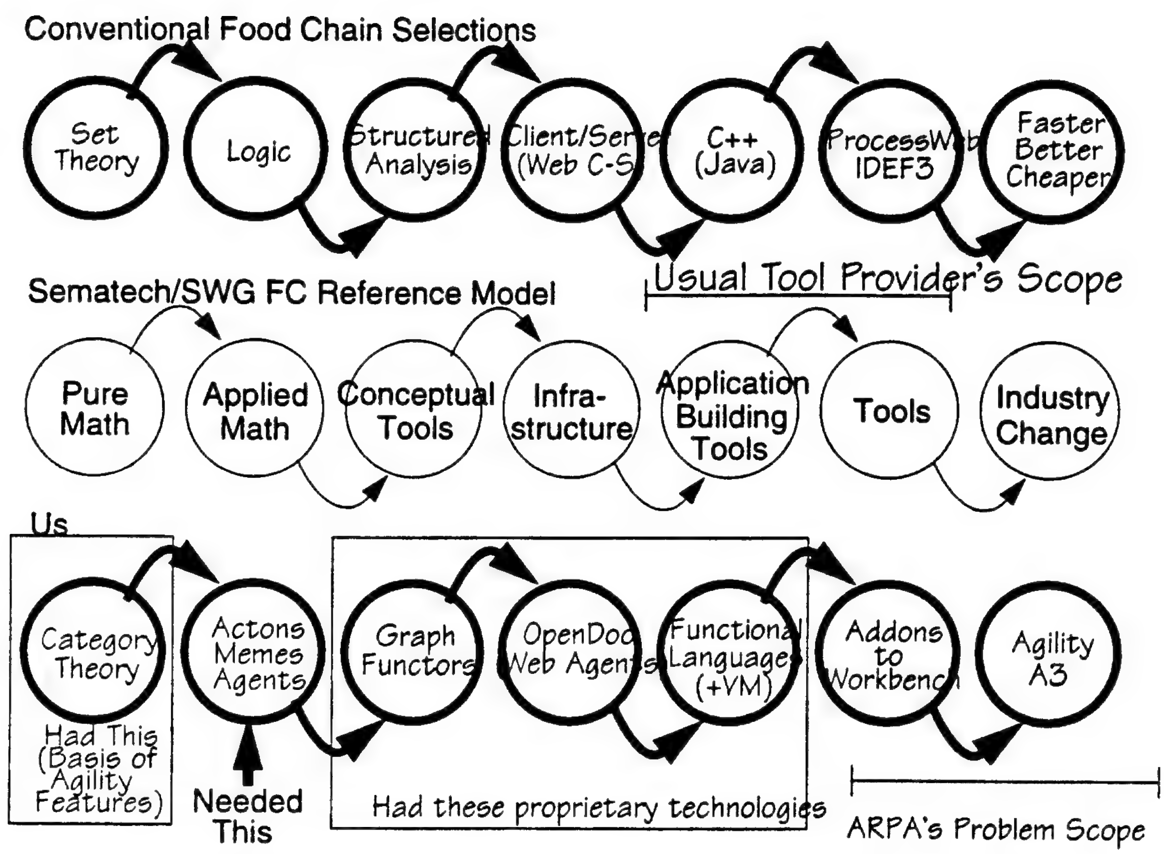

Figure 30-1:We Have to Innovate at Each Step on the Food Chain

has significantly advanced our knowledge of *parameters* and *variables*, and has introduced the notion of *attunement*.

But it's our feeling that the more general apparatus of *constraints* will need to be brought to bear. We did not discuss this in detail at BAST, but noted that some work may need to be done in this area. Because situations are by definition soft (and we hope Ssoft), reasoning about them is necessarily indirect. Reasoning over their *type domains* seems natural.

Characteristics which bound types are well handled by the notion of constraints, and as well there happens to be a mature collection of techniques for reasoning over constraints. We're particularly interested in this as the generalization of *metrics* is to *constraints*.

We see an advanced phase of the project looking at engineering situations (AVEs) for specific effects, and we expect that this will involve operations over types. One stated goal is to work with pattern matching from existing cases, broken down by processes.

So we felt that at least so far as new work in constraint grammars is concerned, it may be better to consider basing it on category theory, which is well suited to dealing with functional descriptions of types.

30.5 Category and Set Theoretical Bases

[Perhaps a category theoretical rethinking of some mechanics is in order.]

Actually, we made a more general recommendation. We do not know how far the approach of measuring and indexing communicative act topologies can be taken. But we expect quite a bit further than we have gone. And particularly, we expect that some rules of thumb can be derived to enhance the agility (or some other property) of the target processes and system.

This is a topological problem. And it would be good for this if the operators on the right hand side, the hard side, were revisited in category theoretic terms instead of set theoretic ones as it currently stands.

Generally, this simply responds to the shift from fact-based, set logics (languages) to action-based, category models (and languages). Specifically, this shifts the analytical emphasis to a bias of behavior-based prediction, rather than fact-based understanding. It's the retrospective versus projective issue that figures so strongly in the business domain.

Old	New
Fact	Action
Noun	Verb
Infon	Acton
Set Theory	Category Theory
Static Features	Dynamic Features
Linear Logics	Algebras
Hierarchies	Directed Acyclic Graphs
Procedural Programming	Functional Programming

Table 30-2: Comparison of Two Perspectives

Set	Cat
Based on things (facts) and relationships (Calculus) among facts	Based on functions and how they are related
Time captured as states	Time built into the concept of functions
Numbers from collections	Numbers as a result of physics
Creates an abstract reality	Creates abstract mechanics of reality
"Behavior"	"Physics"

Table 30-3: A Comparison Of Set and Category Theoretic Perspectives

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31 An Extensible Framework for Special Tools

[Situation Theory could, if extended, serve as a representational framework for the diverse uses represented at the workshop.]

The vision that came out of BAST was especially promising because it provided a common framework for so many diverse projected uses.

The common ground is a sort of grand convergence of speech acts, objects, agents, language insights and logic-based models under the umbrella of Situation Theory, through actons and related work. We're not using Situation Theory as a theory so much as a *representation framework* and a basis for building new and leveraging old analytical tools.

Several of the special interest communities could leverage their existing work through benefit of this new framework:

- Work and Technology Institute studies how soft issues can be brought to bear to create High Performance WorkForces [KBMY96]. They can use Rosenberg's work without significant extension to do useful modeling immediately. They'd like to do *data mining* over their own case base.
- The IMPACT Lab at USC (sponsored in part by Steelcase) was particularly interested in applying object oriented programming techniques to create situation-aware programs.
- In a similar vein, Industrial Technology Institute (ITI)was looking to merge their agent oriented experiments with Situation Theory. ITI has done a great deal with agent-based systems and emergent behavior for control systems.
- The Automation and Robotics Research Institute (ARRI) has a continuing program in enterprise engineering tools and methods. They already recognize the eminence of social dynamics, but have no way of formally modeling them in an explicit way.
- Sirius-Beta would like to perform pattern-matching of implied causal behaviors of social systems, using topological and group theoretical tools.
- Steelcase would like to be able to impute and engineer social effects from the physical infrastructure (office environments).

It's notable that each of these approaches expects to work in a different analytic environment, they each can see some value from a Situation Theoretic representation framework.

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32 Future Action

[Actions that will continue the soft agenda are noted, including several things in the works.]

Cutting edge research in the information sciences almost always has some key government sponsorship in its pedigree, either DARPA or the National Science Foundation. Situation Theory does not. It was lucky enough get an early and sustained boost from a private donation to Stanford's Center for the Study of Language and Information.

(BAST was sponsored by a fluke of sorts. A particularly farsighted Steelcase researcher participated in the AVE Focus Group and was able over time to explain the advantages of the approach. Steelcase and the project then jointly sponsored BAST.)

Situation Theory is unlucky in the same regard. Since it has no NSF legacy, none is likely to be forthcoming. It's a highly interdisciplinary approach, especially now, so it hasn't clearly fallen into anyone's charter as *pure* research. Academic politics being what they are, this could be difficult to remedy.

But we've brought an new application to Situation Theory, though the foundation had been well set by Devlin and Rosenberg [DR96] and others. The engineering of social dynamics in the business enterprise is such a critical component of the nation's wealth that we believe it manifest destiny that government sponsorship as *applied* research will be forthcoming.

We also believe that we are not too far from a critical mass where private investment will appear to develop specific tools, perhaps along the lines of our suggested tool strategy.

We'll seek to have the work continued:

- We'll report to NSF on the results of BAST and related workshops, highlighting the importance to the business enterprise and the probability of making headway against some intransigent problems that relate to national wealth.
- We'll suggest that the Department of Defense, together with key prime contractors, take a look at the theoretical leverage afforded by even the most rudimentary and incomplete soft modeling capability. After the debacle of the B2, and with the specter of the upcoming strike fighter costing *hundreds of billions of dollars*, even small real percentages of effectiveness are worth exploring.
- We'll continue to work with commercial tool developers to introduce these ideas into a new generation of tools to address the soft problem in something more than an intuitive manner.

These three threads overlap with the general recommendations for followon work as well as the *tool strategy*.

We've already had BAST 1 ½, a mini-workshop during the biannual Situation Theory Conference: *Information Theoretic Approaches to Logic, Language and Computation* (ITALLC) in London. And a large BAST2 is scheduled at Stanford in the last week of February 1997. Results of that session will be posted on the metrics web site at:

<http://www.agilityforum.org/Ex_Proj/MAVE/mave.html>
(kindly provided by the Agility Forum).

There is also a BAST mailing list which can be accessed at that site.

We expect to cobble together a larger BAST community by cross-fertilizing among four groups of researchers with which we are involved:

- *BAST*: The BAST workshops themselves are likely to find sponsorship somehow and continue. The ideas are just to strong to have it blink out. (Contact Keith Devlin, devlin@csli.stanford.edu, or Ted Goranson, tedg@infi.net)
- *International Society for Group Theoretic Cognitive Science*: this is an informal, interdisciplinary group which is tied together by the application of group theoretic mathematical concepts to various elements of cognition, reasoning and knowledge. An email list is maintained. Contact leyton@paradox.psych.columbia.edu or Ted Goranson, tedg@infi.net
- *FIS: Foundations of Information Science*: the FIS group supports major interdisciplinary meetings of which there have been two, both reported in the journal BioSystems. What unites these researchers is the shared search for the *science* of emergent, self organizing behavior in natural systems. Contact Pedro Marijuán, marijuan@mcps.unizar.es, Koichiro Matsuno, kmatsuno@voscc.nagaokaut.ac.jp or Ted Goranson, tedg@infi.net
- *International Society for the Interdisciplinary Study of Symmetry:* ISIS-S is quite a large and inclusive group which ranges from the purely intuitive artists to group theoretic physicists. The idea is explore insights related to symmetry through diversity. An interesting quarterly journal is published and ambitious semiannual congresses are held, three already. Contact Denès Nages nages@bukko.tsukubs.ac.jp or Ted Goranson, tedg@infi.net

There's a grand meeting/workshop of all four planned as part of the ISIS-S confab in October, 1998 in Haifa. We plan to use that as one major punctuating point for the greater BAST research agenda. The following section is the brief report done for FIS96:

32.1 Soft Mathematics and Information Dynamics

[One action was to find a better metaphoric scaffold for emergent behavior than memes. We think we have found this substitute.]

32.1.1 Foundations of Information Science

[A second gathering of interdisciplinary scientists to look at new principles of systems with an emphasis on emergent behavior. Principles that may be of use to the project's followon were synthesized.]

In June of 1996, we attended a remarkable meeting in Vienna, the Foundations of Information Science (FIS96). This is an interdisciplinary group of scientists, drawn from physics, chemistry, biology, and the social sciences all of whom are exploring new concepts in the nature of information.

Several of these researchers had discovered some deep organizing principles at work in their discipline, that there was some self-organizing phenomenon at work, with *information* as the central agent. Though the disciplines vary, the basic definitions and underlying dynamics appear in many respects similar.

Mainstream theories of information, coming largely from computation and linguistics, were inadequate to support cogent scientific investigation along these lines. So we need to investigate new approaches to information dynamics based on these insights. In various discussions, I discerned three high-level principles, which are briefly sketched below.

32.1.1.1 Horizontal Information Flow

One conventional view of the laws of nature holds that the laws are extrinsic to the behavior of systems, that the operation of the clock is somehow of a lower order reality than the design and creation of the clockworks. Scientists usually work to discover how a specific clock works, rarely gleaning insights into a larger order of things (e. g. how clocks are designed).

Most presenters at FIS96 showed evidence that, in effect, the clock may be designing itself, that the organizing principles of the universe are intrinsic, resulting from certain dynamics of information. These seem to include self-replication and an *evolution* of sorts to higher forms of information, new levels of organization. For convenience, I've termed this projection of information the *horizontal flow*. (Conrad 96 uses the concept of horizontal and vertical flows.)

Other papers in this volume recount cases which illuminate that horizontal principle, so we won't dwell on them here. In general, the horizontal flow is from simple (or smaller) systems to more complex (or larger) ones. Thus, extremes of the horizontal flow would range:

- (in physics) from elementary particle dynamics to astrophysical behavior;
- (in chemistry) from molecular dynamics to the behavior of materials;
- (in biology) from intracell dynamics to life in complex animals and plants; and,
- (in social systems) from the dynamics of self to societal behaviors.

In each case, it's useful to describe the phenomenon in terms of the behavior of information, with the serendipitous result of providing insight into why the law is what it is. The notion of *emergent dynamics* (or perhaps *self-simplifying dynamics*) is central to this flow with behavior of components percolating to the higher form, as in molecules to crystals for instance, and back down. (Matsuno 93, Marijuán 96).

32.1.1.2 Vertical Information Flow

What's new and radical in this prospect is a possible grand unified idea of information for all sectors of the universe. Whatever the dynamics of information in each of the four (or however many) broad horizontal areas, they are likely similar in important respects, and effects are passed on *up* the line. Thus, organizing dy-

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namics at the physical level support and contribute to the chemical level, and so on up and down a vertical chain through biological systems to societies.

This *vertical information flow* is a generalization of an idea which includes intermediate steps (Conrad, 95). For instance, an understanding of many of the dynamics of biochemistry is improved by considering the exchange of information vertically between chemical and biological organizations.

This linkage is a basis for the interdisciplinary agenda fostered by FIS.

32.1.1.3 Extropic Causality

Implicit assumptions include:

- much of the information dynamics are common not only within layers, (physical, chemical and so on) but the propagation of information between the horizontal and vertical flows may be similar;
- the underlying impetus is toward certain self-organizing structures, a *selfish* tendency which we call here *extropic*, meaning anti-entropic; and
- it is fruitful to understand the extropic impetus not only as it applies to laws governing phenomena, but also the underlying laws governing the generation of other laws. This would imply that there is something unique about the topmost layer, the societal layer where human cognition occurs.

32.1.2 Importance of Social Information

[The social level (the BAST level) is the highest vertical level. Extropic emergent dynamics can only be meaningfully be studied from that level.]

32.1.2.1 Relevance to the Foundations of Information Science Agenda

Several models of extropic information systems were presented at FIS96, representing the bias of each presenter's discipline and vocabulary. We expect that each discipline will bring concepts and tools that will illuminate the whole, but we expect that the most powerful underlying formal tools will come from the two extreme layers of the vertical flow: physics at the bottom, and social systems at the top.

In this new interdisciplinary agenda, we would expect that the most useful *mathematical* concepts will be those which first found utility in physics, such as group theory, and ideas of causality and invariance. (We revisit this idea below.) But we are persuaded that a very fertile area for cross-disciplinary insight is the societal arena.

- Representing the pinnacle of the vertical flow, the social domain has the most complex array of information dynamics. Insights at this level are more likely to scale *down*, than those in lower levels are likely to scale *up*.
- Information at this level is intrinsically recursive since the understanding of FIS will be in terms of the same type of information whose dynamics are being

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described. This is not a trivial consideration.

- Moreover, it may be the case that the selfish dynamics of groups could add another recursive dimension if one takes the perspective that they drive the extropy of their own system.

The bottom line here is that we find it rewarding to consider the interdisciplinary spectrum of FIS as a layered system with societal dynamics as the most interesting, challenging, and rewarding case. We expect an extropic mechanism of some sort should be the goal of interdisciplinary focus, and that a memetic or autopoeitic paradigm may be useful.

32.1.2.2 The Business Enterprise as the Target

Incidentally, the business domain is a high value subset of general societal interaction:

- It is a well-behaved subset. Business enterprises assume that everyone is interacting/collaborating for selfish reasons which can be economically evaluated; the goals are singly-directed, unlike general social enterprises.
- Commercial collaboration is primary infrastructure for human collaboration, providing a basis for much else which organizes society. It appears that commerce, broadly defined, predates agriculture and government, and is a basic driver behind the development of language. Business enterprises are currently so poorly understood and engineered that any new insight could lead to significant benefits of multiple kinds. Small insights will likely yield great returns.
- Sponsorship for work in this new FIS agenda might be found from parties interested in the science behind enterprise engineering, in devising environments where creation and collaboration are maximized.
- The need is tremendous. For complex systems such as military aircraft the vast majority of dollars goes to support societal infrastructure of collaboration. Since we currently do this so poorly, over a billion dollars per plane is the cost in the B2 bomber. The collaboration cost of the next generation is in the *hundreds* of billions. Note that this is independent of the engineered and manufactured value of the plane, which is a minority of the cost.

  We use military planes as only an indicator of the general problem. Their costs are better tracked than with comparable complex systems in the civil sector which is vastly larger (and more costly).

32.1.3 Need for New Mathematics

[FIS needs the soft math proposed at BAST; FIS scientists could help.]

In our work, we have targeted an agenda of approaching social and cultural information dynamics in the business sector. Specifically, we are interested in new analytical tools and perspectives that will improve existing models and empower new models of collaborative enterprises. In doing so, we've adopted the FIS-inspired taxonomy described above, looking for the deep physics involved. It quickly

became clear that in addition to the conventional scientific challenges there were fundamental limits in the mathematics itself.

In particular, the nature of *logic* to examine information systems, which are presumably elucidatable requires that special provisions be built into the logic to handle phenomena which we don't fully understand. We'd term such phenomena *soft* phenomena, following the differentiation of hard (physics, chemistry) and soft sciences (psychology, anthropology). A mathematics with such a capability would be a *soft mathematics*. Logics which are extended through modes, fuzziness or relaxation are extended superficially and are unsatisfactory for this use.

We conclude that progress in this area is essential for establishing new conceptual beach heads in social information and providing a framework for a layered FIS.

32.1.3.1 Situation Theory and Soft Mathematics

Fortunately, there is a area of mathematics which could, with some effort, be leveraged into the soft mathematics domain, *Situation Theory*. This work apparently began as a response to Chomskian linguistics, which looks to the underlying structure of utterances to understand the nature of information conveyance. Instead, Situation Theory holds that only a part of the information conveyed can be found in any utterance, that much of the information is held indirectly, in various situational and notional contexts.

This view was first expressed in Barwise 1983. A substantial, well funded, research effort followed, lead by Stanford's Center for the Study of Language and Information for the next decade. The major practical result was the theoretical basis for ontological definition, now widely used in the knowledge representation community. For the exchange of information between machines, this provides a basis for describing the representation methods used as well as basic assumptions about the world and context of the originator.

A well-developed formal mathematics was created which treats situations as first-class objects within logics. Situations usually lack a complete explication and are thus soft objects in these logical systems. Thus, Situation Theory forms a ready basis for reasoning about soft (meaning not fully explicated) information. A current review of Situation Theory is Devlin 91.

Indeed, Devlin and Duska Rosenburg, a social anthropologist, collaborated to apply Situation Theory to a limited but practical problem of cultural mismatch in a business setting (Devlin 96). And Devlin has proposed a specific agenda that leverages Situation Theory as a basis for a soft mathematics (Devlin 97).

While Situation Theory is not, in itself, a basis for a new theory of information, it does provide foundations for a promising representational framework for investigation.

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32.1.3.2 The Agenda for Business Applications of Situation Theory

FIS96 was held in June. The month before, a project of the Defense Advanced Research Projects Agency (DARPA) together with Steelcase Inc. sponsored a workshop to explore in detail the soft mathematics agenda. This meeting, Business Applications of Situation Theory (BAST), had as a general focus the layered FIS agenda described above, and specifically, as the title suggests, the engineering of agile collaborative business enterprises. See Goranson 97.

That workshop produced three results:

- An extension of *softness*. Conventional Situation Theory has the notion of softness that the situation is not fully explicated for some reason, but that it *could* be. We extended the notion to situations for which we do not have the ability (at least currently) to fully explicate. Most of the social/psychological dynamics of interest have no hard, concise laws, nor any on the horizon.
- The addition of the notion of *actions* as first class objects. Conventional Situation Theory manages facts, but the domains of interest are dynamic with concern to the nature of the dynamics. Therefore, we sketched a definition for a unit of action which can be assimilated into the formalism and provide some leverage to address our problems. Specifically, there is a mapping between these action primitives and information-based agents of some type that could exhibit emergent organization, extropy.
- The longer range agenda of migrating the basis of Situation Theory from the familiar definitions of set theory to the potentially more leveragable category theory. We expect the FIS agenda to rely heavily on the topological features of information and its carriers. The syntactic view of category theory is better suited for this than is the semantic perspective of set theory.

32.1.3.3 FIS and BAST: A Promising Agenda

In summary, we believe that the FIS agenda is important. The scope is highly interdisciplinary, and a radical new common vision of information dynamics will emerge. That vision will likely relate dynamics in a layered way with *vertical flow* through the layers as a key link.

All layers will have an extropic mechanism (a *horizontal flow*) of some kind based on a common law which describes the emergent behavior of primitive information carriers or actors. In both horizontal and vertical flows, a highly promising approach is to work at the top of the flow, in the human, social/cultural/language layer exploiting recursive principles.

In any case, fundamentally new mathematical tools will be required. Situation Theory extended both in scope and nature to support a soft mathematics could support some of the new needs. Fortunately, sponsorship of this agenda is promising because of its business applications. There is robust work currently underway.

Part 4, Tool Strategy

Part 4 is for those who need more detail about the defense case and how to develop tools. It is a little more technical.

33 Abstract

In order to set the stage for a case study, a specific missile problem is noted. We note the difference in the defense legal system and explain it historically. Using these insights, an ideal defense supply chain is proposed.

After giving, in detail, a scenario we studied then set aside, we set up the case study scenario. The questionnaire we used is reproduced. Then the results are reported. Within the case study, we had occasion to consider how we would work with methods of consultants; how we would integrate with a representative system is reported.

We then turn to tools whose need was indicated in the study. Several tools are described. One of these tools, the one most immediately needed has been prototyped. It's internal structure is given in detail. That tool automates an algorithm which is central to the metrics. The algorithm is outlined here.

In terms of future tool actions, we mention our own special strength we bring to future toolsets and outline how we will integrate with other projects.

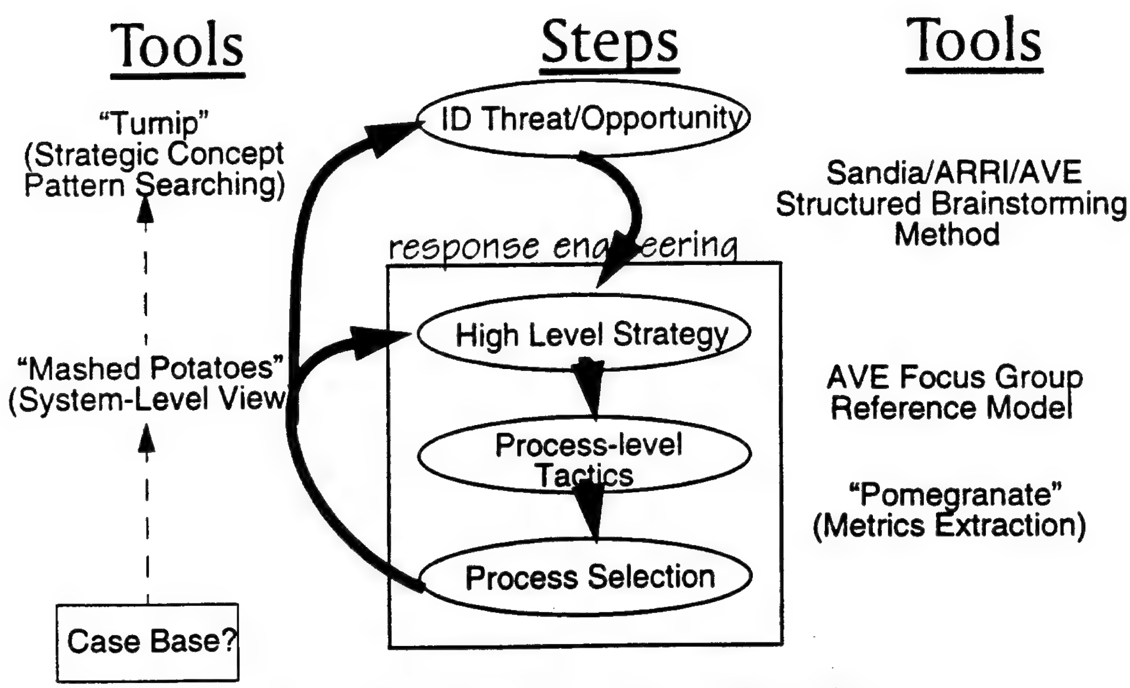

Figure 33-1:Tools for Each Step of the Way

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Part 4, Tool Strategy

34 Context For a Defense Scenario

[We set up issues peculiar to the defense situation in agility.]

This section focuses exclusively on issues found in the Defense Agile Virtual Enterprise that are unique to defense. The purpose is to provide a scenario for a case study.

34.1 A Serious Problem

[We give an example of a system where the lack of agility in the supply base is apparent.]

The U. S. Air Force has a missile gap, and this one is real; it could cost lives. Our fighter airplanes (and those of many allies) rely on a specific air-to-air missile as its primary weapon in dogfights. (Dogfights are still considered the primary threat for air superiority on which essentially all current strategy is based.) This mainline missile, long called the Sidewinder, in is current advanced version is called the AIM-9M (Air Interdiction Missile).

In 1985, U. S. intelligence was shocked when a new, then-Soviet, air-to-air missile was observed in Finland. This missile, which we call the AA-12 (using the NATO designation of Air-to-Air) is superior to our missile in a couple of key areas. If our F-14, 15, 16 and 18 pilots meet in combat with a well-trained MIG-29 pilot with this missile, we will likely lose. We could have met this missile over Iraq with disastrous consequences, and the chances of encountering it soon in another conflict are substantial.

As soon as Israel received word on the missile threat, they were able to design and field a missile with equal or superior capabilities. This process took six years, and the missile is now flying. Subsequent analysis shows that the original Soviet development took five years. (The French now also have a fielded response.)

The U. S. started at the same time as the Israelis, and we are now in the midst of a planned 17-year path to fielding our answer, the Raytheon/Hughes AIM-9X. But all weapon systems--every one in the U. S.-- experiences delays and cost overruns. Surprisingly, the time and cost penalties are amazingly constant, and these have been studied and described by Norm Augustine, currently president of the largest defense contractor in the world, in The Laws of Augustine [AUGU83]. Adding in this constant, we could be looking at a *24-year response cycle*.

Why does it take the U. S., the world's richest military power, holder of the most advanced military technology anywhere to take from 17 to 24 years, under severe threat, to do what others can do in 5 or 6 years? All the reasons will be debated for some time to come. But at least one reason is already clear: our defense industrial base, particularly our missile supplier base, is broken.

A recent study concluded that for a long time, beginning shortly after the beginning of the Reagan buildup, we have been losing our supplier base at an alarming rate. It's not because defense work is not profitable; it can be. It is because the difficulty of doing work for the government, even as a second or third tier supplier, forces a company to commit fully to being either a defense or commercial supplier because of the way that processes are constrained.

Two efforts at *improving* the Defense Industrial Base, Lean, and CALS), may have actually made some elements of the situation worse. A problem with lean practices results from prime contractors moving to reduce and *prequalify* their supplier base. This lowers the cost to the prime in the short run, because it is easier to *control* the suppliers, forcing them to conform (or preselecting them because they do conform) to a wide variety of VE-related practices, in fact all of the ones that the metrics cover.

This means that Westinghouse (now Northrop Grumman), for example, will do business only with smaller clones of itself--clones in regard to practices--and only with companies who provide a need that is in the current profile. This lowers their cost of doing business within the relatively small scope for which the *Westinghouse* VE was engineered. But this limits a primary reason for creating interesting VEs: the ability to team with exceptionally different types of organizations compared to your own in order to create a new competitive advantage.

In the defense case, the result of these practices is that what had been a large, flexible, and innovative pool of businesses has evolved into a set of small, stable communities that are associated by sector and often by prime contractor. The result is both costly and unagile. In situations where capabilities need to be stretched quickly, as in the AIM-9X, the ways of bringing new skills and technologies into this pool are expensive both in time and dollars.

34.1.1 CALS

[Though beneficial in other areas, the electronic data standards effort known as CALS has made the problem worse.]

This effort began in the mid-1980s as a response to the high costs of supporting weapon systems resulting from poor technical data. Originally named *Computer Aided Logistics System*, it has evolved through *Computer Aided Logistics Support*, in recognition that what was needed was a set of technologies and policies for many systems instead of a single new system, and then *Computer-aided Acquisition and Logistics Support*, in response to the insight that processes early in the cycle are involved and improved.

Today CALS stands for *Continuous Acquisition and Lifecycle Support* and lately for *Commerce At Light Speed*, the latter as a result of reaching out to the commercial sector, by including data exchange associated with simple purchasing. In all these incarnations, CALS emphasizes standards as the way to improve the exchange of technical (and associated) data among organizations. The primary discriminator between CALS and other standards efforts is the deliberate attempt to accelerate useful standards by imposing them through mandates on new weapons systems.

CALS is designed to lower the customer's (DoD's) cost, by working with primes. It is not designed to lower the cost to subcontractors of doing business, nor to make it faster and cheaper to associate with primes. There are claims, though, that this will occur as a secondary effect, once the standards involved become widely used and cheaply implemented.

But the opposite has in fact been the case. The requirement to use CALS standards and conventions is just one of a collection of DoD-specific mandates that collectively have forced suppliers either to focus on narrowly *answering the mail* or to give up and abandon the Defense Supplier Base. So agility in the VE, early in the cycle, is compromised in order to effect savings to the customer's view of the product.

Moreover, since the standards don't look at re-engineering the processes, they have an additional effect of technologically freezing existing, possibly obsolete business processes. Naturally, this further counters the ability to change.

Part of the problem is that CALS takes a fairly unsophisticated view of process integration, viewing it only as lowering the cost of exchanging product data across an existing business or functional boundary. Agility adds the more advanced dimension of looking at process integration in including novel business arrangements. Also, agility values the adoption of enlightened management techniques which drive technology, instead of the relatively crude instruments of mandates and official standards.

34.2 Defense-Peculiar Issues

[What's unique about the defense enterprise is the legal system. All else is as it is in the civil sector.]

To what extent is defense a special case?

Elsewhere, we've looked at various ways in which agility can be measured. We have settled on an agenda which looks at how well (in an agile sense) an entity can *aggregate* and *change* its business boundaries once aggregated; also of interest is how agile the entity is, and how agile is the aggregate.

We suggest that the former view is the most comprehensive, greatly informing the others. Also, for each view of agility, the organizing entity is different and might have different elements of agility that would be measured. Here we need to look at the nature of that organizing entity.

We have justified our initial focus on the formation of the for-profit defense manufacturing virtual enterprise. There is reason to ask whether all the other applications of interest, save one, will fall out of a rigorous look at our focus. What are the differences between the commercial and the Defense AVE (*DAVE*)?

First, some observations about the DAVE. Different types of decisions are made concerning each of the four infrastructures in the DAVE.

What might be different in the Social/Cultural infrastructure is motivation. At least at the individual level, patriotic motivation is a force not found in the commercial arena; it could be a significant differentiator. It has been suggested that a security environment profoundly affects the group dynamic. But it is not clear whether that is a cultural issue, since it is a matter of rules and policy.

It has also been suggested that the social dynamics are often influenced by political issues: for example, a weapon system may be built or not depending on the congressional representation of a critical mass of its VE partners. Does this happen in the commercial sector? Airbus, Long March, DeBeers are only a few cases, of

many, politically-driven closed-market situations found in the commercial world. We don't see this as unique to the DAVE.

Concerning the Physical infrastructure, there aren't many special issues. It seems to many observers that the plants and equipment are largely similar. Exceptions have been proposed for nuclear, biological, and chemical weapons manufacture, but even here there are similarities with many commercial enterprises.

Sophistication is not an issue. In some process equipment technologies defense is more sophisticated, but in others they are not. Overall, at root there are no discriminators.

The Information infrastructure issues are also similar. There are only a few possible elements which could be different. One is security, but that is essentially common (with the exception of the rules noted below). One case which was studied had an aircraft operation which was so concerned with *stealth* geometry that its information needs perturbed the entire operation negatively. We argue that only this specific motivator for the perturbation is unique to defense, but that many similar perverting influences exist in both sectors.

One final element is the need for individual parts tracking in some DAVEs. This was pointed out in a dual-use plant where the parts were maintained so separately that the processes were in fact forced to be dissimilar. But again, we suggest that this results from differing rules (the Legal/Explicit infrastructure) and not differing information infrastructure needs. Bottom line: there are no differences here.

Many differences are apparent in the domain of the Legal/Explicit infrastructure. The differences fall into three categories: the external imposition of the Work Breakdown Structure, which determines the business boundaries among partners; the external imposition of policies and procedures in the actual processes; and the common case where reimbursement is accounted by the process and not by the product's value, because free market conditions do not apply.

In the case of selling weapons, there is often another factor: the need to have a government third party involved either as an agent or as a regulator. However, we will not list this as a difference, since there are many commercial technologies which are *controlled*, and many other commodities which are subject to the same influences through tariffs, ceilings, and so on.

The discussion above presumes that the VE is defined in the same way for defense and commercial work, namely as the aggregate of the entities which actually do the work. In this model, the DoD is external, playing the same role--customer--as the *marketplace* does for commercial AVEs.

We don't make that assumption; instead we assume the defense customer plays a role in the DAVE as a bona fide entity. This expands the search for discriminators that we summarized above, and it raises questions about who is the organizer in a DAVE, the DoD or the prime contractor.

If we expand the scope, issues in the Physical Infrastructure show a real difference. The U.S. DoD is the world's largest and most distributed enterprise. The physical magnitude of a DAVE itself is a discriminator. And if DoD is involved in a

military action, the physical presence of the DAVE is (often) brought to a dynamic battlefield. For instance, many defense contractors had sites contiguous to the action in Desert Storm. Downsizing of uniformed combat support personnel is likely to increase this phenomenon. So a possible difference is in the physical dispersion and distribution of production/distribution/repair assets of the DAVE, together with their integrating logistics.

On the Information infrastructure side, the acquisition infrastructure in DoD is clearly separated from the command and control infrastructure. In recent history, this was reinforced with a decision to move advanced acquisition research efforts from the Defense Data Network to the open-access internet channels. Arguably, this was a mistake. But, in any case, driving a wedge between C³I (Command, Control, Communications and Information) and acquisition pushes defense electronic commerce futures closer to those of commercial commerce. The net result (pun intended) is that the information infrastructure issues are the same.

Cultural issues change in this new situation. The patriotic motivation becomes more pronounced when your actions seem both to benefit society and to save individual lives. It's not clear this is unique to DAVEs. There are for-profit life-saving or life-dependent VEs (emergency hospitals and safety in the nuclear power industry, for example). There are enterprises driven by a sense of social/environmental responsibility (Tom's Toothpaste, Ben and Jerry's Ice Cream). There are enterprises, such as unions, where the collective benefit is important.

It seems none of these forces could match the depth of patriotic commitment, but I think the dynamic is the same. There is no substantive discriminator in the social area. Patriotic motivation is one of a number of similar motivators. The difference between it and the other motivators doesn't matter in the agile context.

So, the real differences come in the Legal/Rules infrastructure, and it is here that we propose to direct the discussion to the role of the organizer.

This is the *sole area* in which DAVEs are different from commercial AVEs; the customer acts as the organizer to a large extent. Intuitively, we assume that much, possibly the majority, of the activity of the organizer is in the creation of the legal/regulatory infrastructure. And it has been seen that the actual rules differ between commercial and defense enterprises. It's only fair to assume that the difference in rules results from the role of the customer as organizer.

So there will be an additional set of agility metrics applicable to the DAVE; these will deal with the ability to have an organizing customer and the ability of partners to be organized by it. Moreover, the context will involve some DAVE-peculiar rules resulting from at least some centralized influence over processes as an effect of the organizer's control.

In this context, the DoD acquisition bureaucracy is the organizer/customer, representing both the congress and the combat user.

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34.3 A Key Difference: The Engineering Paradigm

[The legal system difference can be traced to a different engineering philosophy; the customer controls the processes.]

Agility is a broad concept which can be applied in a wide variety of scenarios. In order to focus the test cases for the metrics, we've chosen to concentrate on one scenario beyond others. In no way do we mean to imply that the metrics apply to only this scenario. But it does help to assume a specific context.

Our Focus Scenario is directly targeted at the DoD problem, as well as common commercial situations. We focus on agility in the supplier base; we assume a *prime*, which acts as an *organizer* of the VE. Agility of the prime, in this scenario, is considered differently than agility within the subcontractors.

In the case of the prime, we consider only its ability to agily organize a VE consisting of itself and several primes, ideally with the ability to use novel business interactions. It has an ability to adjust internally that is essential to serving this organizing strength. Potentially, there may be certain agile issues that don't contribute to strength in organizing AVEs. For simplicity's sake, we ignore them in this scenario.

Considering the subcontractors, we focus on their ability to be cheaply and quickly organized, and reorganized, into an AVE. There may be other, unrelated types of agility within each subcontractor. These are ignored in this focused scenario.

It should be noted that it is widely believed that the agility on which the scenario focuses, and that which it does not, are either identical or closely related. But there has been no rigorous investigation of the relationship; this is an area for someone to investigate further.

The focus scenario has special applicability to defense issues. Commercial market forces are not the major driver in the defense sector. In the commercial environment, the *prime* determines the nature of the product, and offers it to the customer. Listening to the customer requires special skills. In the defense sector, the customer, DoD, defines the product or need, often in precise detail. So, market forces that are at work in the commercial sector are less clear, or absent, in the defense sector.

The result is that greater stability is more desirable in defense primes than in commercial primes. The agility that is required is the ability to quickly and cheaply supplement some in-house, protected core competencies with a fluid, robust supplier base. The value that each defense prime brings is its set of core competencies plus its ability to create, manage, and adapt a team. The focus scenario is concerned with these values, which, as it happens, are particularly apt for the missile community.

34.4 A Desirable Future State of Affairs

[Here we suggest an ideal situation as a strategic goal.]

Part 4, Tool Strategy

Here we suggest an AVE scenario that is a special case of the agile defense supplier chain just described. This future state of affairs recognizes that defense needs are substantially different than commercial needs, and possibly will always be so.

We believe that it is unproductive to try fundamentally to change the way that the DoD relates to its prime contractors. That relationship has no commercial analog. Unfortunately, that is currently where most of the attention for acquisition reform is mistakenly engaged. But that is not where the costs from not being agile are being incurred; rather, it is in the relationships with first (and later) tier suppliers. We would like to see a high degree of agility there, which implies ease of moving from being a supplier of commercial goods and services to defense and back.

There are three inter-related ideas that make this vision possible:

- No-clause contracts,
- A skills/process certification agent(s), and
- Indemnifier(s) for unexpected events.

We outline all three below. The metrics need to provide information on them all, but also to provide a necessary enabling foundation for the third.

34.4.1 No-Clause Contracts

[An Ideal would be contracts that contain only what is to be done, relying on case law for what happens when things go wrong.]

We recognize that large, centralized, FAR-based contracts between the government and the prime will be with us for some time to come. But ideally, we'd like to do away with the passing down of all the baggage to the supplier base, which in most cases adds over half of the value of the weapon system.

Currently, the ponderous responsibilities of the prime are passed wholesale to the suppliers. It is a matter of assigning risk. In the commercial world, if a part fails and lives are lost, for example, the supplier of that part may be liable. But in the defense world, if the supplier did exactly as it was told, if it conformed to all the process and other specifications passed down to it by those *above*, it is not liable.

Most of the military systems of interest do involve the possibility of substantial loss of life by their actual customers, so those in the system will not give up this indemnification unless something substantially better emerges.

For this future scenario to work, we need all three innovations noted above. The first of these is a greater reliance on the case base for that component of the FAR which deals with corporate ethics and contractual responsibilities. It should be possible to encourage prime-sub contracts which mandate ethics, but rely on the case base instead.

We believe that when successfully applied, the result is great agility and an openness of the marketplace to commercial and start-up entities. More important, we believe that the cost savings to the system will be greater than the additional costs of litigation that the system could promote. In the movie industry, this is

clearly the case, and economic studies done to commercialize the formerly-Soviet supplier base indicate that it could also have been so there.

In other words, we'd like to see the same prime-sub contracting principles we see in the most agile commercial systems.

34.4.2 A Process and Skill Certifying Agent

[Another ideal would have an agent that brokers partners and certifies skills.]

Part of the reason for the unwieldy contract provisions for subcontractors is to ensure that processes will integrate well when the VE is formed. Certainly, this is an important issue; it won't happen of its own accord with high confidence, so the DoD makes it happen, ensuring that it will happen by specifying and requiring specific processes in detail.

The problems with this are well known; the costs of avoiding fraud, waste, and abuse are greater than the sort of waste they seek to avoid. Even in the case where the overall process integration is good, it differs from commercial practice and/or preferred practice, so it costs more. But often the military specification is not better, or even as good as, commercial practice. Maintaining these specifications is a large, expensive job. Many of the processes of relevant interest evolve rapidly, and it is impossible for the central authority to catch up.

The alternative to rewriting defense specifications to conform to commercial ones, or substituting formal military specifications for formal commercial ones, can only partly and insufficiently solve the problem. We would still have a lumbering central engineering authority mandating processes. Federation among the partners in the VE is required, but we cannot have anarchy in the process selection and certification.

But we do have an agent involved that is close to the processes and has what could be the proper mix of federation and central coordination--unions. The defense industry is heavily unionized. That this is so should be no surprise: large, brittle organizations attract strong adversaries in order to preserve justice and balance in the workforce where needed.

Where the role of the union has in the past often been reactionary, a new role can be carved out. Why not respond well if the unions were to return to their heritage in the guilds? It is entirely possible to envision the union as an agent which certifies that the skills of a worker is adequate, that the processes that the workers use across many firms are consistent and readily integratable, and that those processes represent best practice.

We believe that this is possible. The positive role that unions are currently playing in exploring agility (at The Work and Technology Institute in Washington DC) is encouraging, and we believe this goal to be theoretically within reach. By the way, this approach (agile unions) would reflect another structural advantage that the U. S. has over its competitors and adversaries.

Both the lightweight contract and the certification agent depend heavily on being able to protect themselves from unexpected and extreme circumstances. Therefore an agility-based indemnifier is required as a necessary condition.

34.4.3 An Agility-Based Indemnifier

[The third ideal would be an insurer who evaluates agility and lowers risk costs.]

The final big idea of the three is more centrally based on agility. We want VEs to form quickly and cheaply and to work in key respects as well as centrally-mandated enterprises. But the question always arises: who gets stuck, if something unexpected happens?

The cases that are interesting are high-value, complex, high technology systems that must perform with very high quality, and whose technology is always new and changing. Something always goes wrong in creating these systems; that's the nature of the beast. If it were not so, agility would not be so important.

We propose another agent in the system, an indemnifying agent. We believe this would be a relatively minor outgrowth of an existing insurance industry, which in fact performs a similar function today in the movie business.

How it would work is this: the parties (prime to supplier, or supplier to supplier) agree to do certain things assuming not much untoward occurs; this is our lightweight contract. Also, at a fine level of granularity, the unions certify skills and processes, but this also assumes that not too much deviation from the base case occurs.

A third party evaluates the situation, and judges the ability of the suppliers in combination to respond to the changes that, while unexpected in detail, can be reasonably expected overall. That agent is paid to cover problems outside of the planned base case.

Two things happen. First, the system automatically becomes less brittle, because every competitor is going to want to have its capabilities within the ability to respond to change. They will want to lower their *insurance* cost as a business matter. This means that normal market forces will be brought into play not only to give incentive for agility, but also to reward the VEs that have achieved the best balance of agility versus insurance.

Second, a new cost is added into the system, that of paying for insurance for possible events to which the system could not previously respond well. This new expense should be far less than the amount saved, because of the effect that it will have on building agility within the VE and because of the costs avoided from centralized management.

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35 An Alternative Scenario

[We set up an alternative defense aerospace scenario.]

Our case study, which we describe below, has fairly modest aspirations. We take a typical Type 3 AVE, led by a conventional prime. We target agility in the supply base and have a specific ideal in mind. (The three characteristics described above are given not as a realistic state, but an ideal vision.) But there is another cogent DAVE scenario which we did not pursue. Perhaps it even more meaningful.

The defense acquisition system is based on the idea of designing and manufacturing the *right* system. It's supposed to be apt for the missions and reflect the most beneficial product and process technologies when fielded. Essentially all manufacturing research is design research, to increase the changes of getting it *right the first time*. *Concurrent Engineering* (CE) and *Integrated Product and Process Development* (IPPD) are two examples of this thinking.

They address the famous wisdom that most of the cost of the system is set very early in the life of the design. CE and IPPD allow more iterations and alternatives in that short period, and carefully provide for insight into the downstream implications of early decisions.

But something is wrong. That can never be sufficient in dynamic situations where technology and missions continue to change throughout the whole life cycle, not just the first 20%. History shows that essentially no major weapon system has been right the first time. It's just impossible, and more likely in current times as missions evolve more quickly than in the past. Technology changerate is increasing.

Our alternative scenario addresses lowering the cost of getting it right the *second* (or third...) time, by relaxing the period of time that design decisions need to be frozen. In the defense environment, all major design decisions must be made in the very early phases because you need to lock in your suppliers (and their processes). It's the way the system works.

The Work Breakdown, who does what, becomes a part of the legal fabric of contracts and responsibilities. If the supply chain were agile, if the members and processes could change in midstream, then basic design decisions could be changed much later at low cost- indeed all the way through. We did not work through this important scenario in the case study because it assumed unrealistic changes in acquisition law. We wanted a scenario that a prime could implement today.

For reference, we worked through an example with this alternative scenario and distributed it directly to key firms, and posted it on the web site for a year. The general feeling was that similar costs would apply if the metrics were used in this scenario, but with greater benefits to the Department of Defense. A summary of that alternative is given below.

35.1 Background

[Who you are (a defense prime), what your goal is (in winning contracts).]

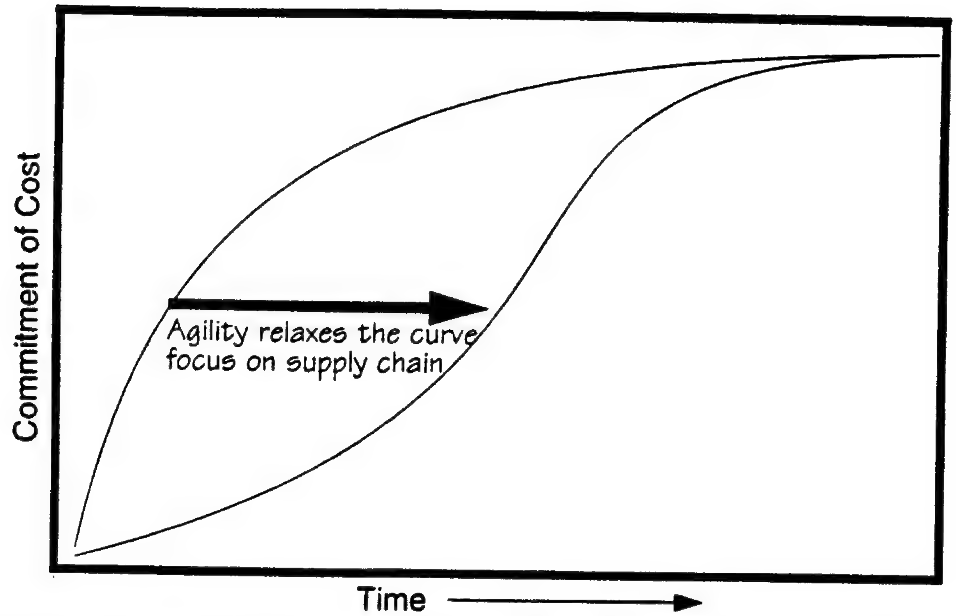

Figure 35-1:An Agile Supply Chain Allows Design Changes to be Made Later

In this scenario, you work for an aerospace prime contractor which supplies tactical missiles to the U. S. Department of Defense (DoD). The situation is highly competitive, and you are going head-to-head with a competitor for an important air-to-air missile contract, which may affect your chances for survival. This is quite a real scenario in today's environment.

You and your competitor compete on *cost*, which hurts you both. But you could get extra points for advanced technology in your product in the contract-awarding evaluation. However, your DoD customer is sensitive to and avoids technology-induced risk in its project.

Both of you are starting with similar, low-risk technical approaches, but you have a smart, inventive engineering staff. It's probable that they can come up with design alternatives late in the design life cycle, well past the ordinary time it takes for you (and your competition) to adjust your supplier chain.

What agility can do for you: if you have agility built into your supplier chain, so that it can adjust to major redesigns late in the game, you can win the contract, and win it on advantageous terms.

35.2 Your Company's Possibilities

[You'd like to keep design options open until late in the engineering cycle.]

As we've said, your company makes missiles, and they have decided (through the strategic planning process) that competitive leverage can be gained by focusing on technology improvement in the design of the steering system. You and your competition were planning on using metal fins, which is a low-risk decision.

However, your company's engineers have two design possibilities that would greatly increase the performance of the missile and improve your chances of winning. But both design options won't be ready until late in the development cycle, well after you normally freeze your production assets, in this case your supplier base.

This missile is controlled by metal fins at the rear of the missile tube. The first option is to replace the metal fins with ones made of an advanced composite material. These would be both lighter and capable of standing higher temperatures. Most important is that because the material is far stronger, the fins can be larger, making the missile more maneuverable. The customer's evaluation criteria value that performance improvement. It means that you would be competing on product performance rather than cost; your company would much rather have a high chance of winning on performance, than take a scant chance of winning on cost.

The other design option is to do away with fins altogether, making the rocket nozzle out of the same composite and gimbaling it so that steering fins aren't needed. Adoption of this option would guarantee winning the contract on merit and open possibilities for profitable growth in the product line.

Unfortunately, your engineers will not be able to engineer sufficient risk out of these alternatives until 200 days before production in the first case, and 100 days before in the second. Your normal best date for freezing these decisions is 300 days, which is controlled by lining up and preparing suppliers. At the 200 and 100 day marks, your engineers expect to be able to tell you for sure whether the options are viable.

Therefore, your company seeks sufficient agility in the supplier base for this section of the missile to allow them to adapt to the alternatives if your engineers can get the designs ready by engineering out unacceptable product risk.

35.3 Structured Brainstorming

[You brainstorm your strategies.]

Incidentally, the strategic planning is a directed series of simulations, conducted at different levels of detail. The idea is to discover the strategies that are most beneficial and include conventional non-agile features, as well as the agile ones we add.

But such simulations are usually directed by the senior management on the basis of intuition. Our investigations of the dynamics which support the metrics have also indicated a structured brainstorming method which can direct the strategic simulations. Since it is relevant to the example, we outline it here.

The idea is that the best agility will leverage natural forces in the business environment and will key off of strengths that occur in the enterprise seemingly of their own volition. We've used the concept of a meme from the study of self-organizing systems. A meme is a self-perpetuating entity, usually an abstract entity of some kind, which adapts and spreads on its own. For example, the common-law

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Note: this chart is different from, but related to, the one which shows costs of design freezing.

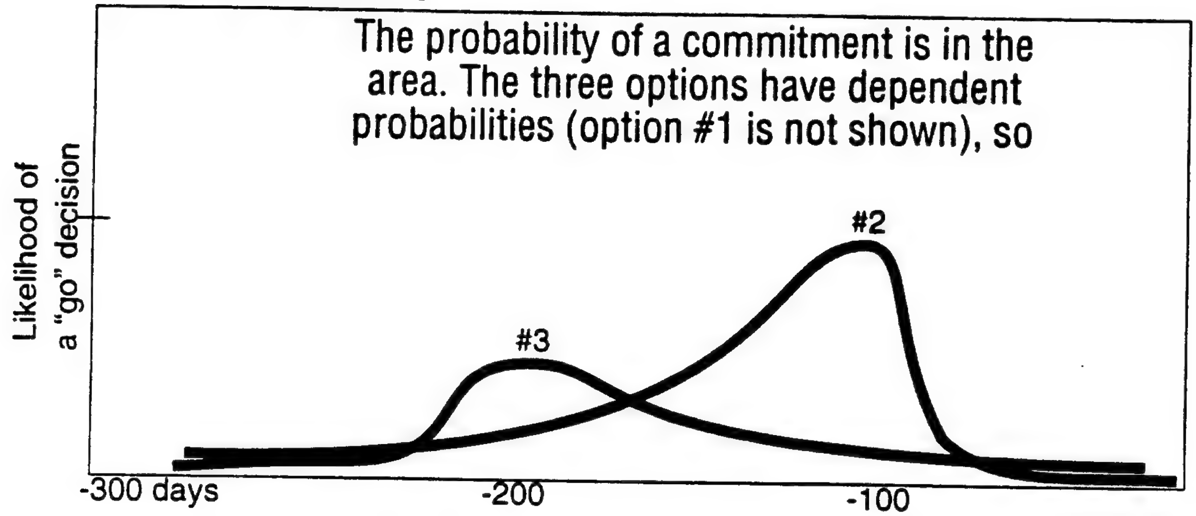

Figure 35-2:You Must Design the Supply Chain for the Probability of These Late Changes

based no-contract contract of the whaling example is a meme which adapted to survive.

We've found a meme which is associated with centralized control and code-based contracts, which has a French/Latin heritage, and a competing meme based on decentralized control and common law (the invisible hand of the market), which has a Viking/English history.

The structured brainstorming approach is based on a few basic religious issues. Participants play roles, often taking a religious perspective or world view that is contrary to that which they normally hold. This has been effectively developed as promising tool by the AVE Focus Group.

What's interesting about the defense sector is that it has an unhappy mix of these two memes, the central planning one in the relationship between the customer and the prime and the decentralized meme in the relationship between the prime and its suppliers. This is a major cause of difficulty in the defense sector, a difficulty which is not found in its civil counterpart.

This is such an important factor in the missile sector that we have structured the scenario to illustrate agility that spans the influence of the two memes. Strategic planners in the missile example would have looked at the advantageous implications of agility in this respect and planned to include those considerations in their virtual manufacturing simulations.

35.4 Results Of The Strategic Planning

[As a result of the strategy, you are given supplier options, a target and an agility budget.]

Your company's planners have employed the metrics in a Virtual Manufacturing scenario, looking for breakpoints in the risk-payoff curves. (This process is based on the same metrics and is also addressed by our project, but is beyond the scope of this example. It was through the strategic planning process that the engineers' decision dates and associated probabilities were established, as well as the profitability of pursuing this *agility* strategy.

What they have provided you is an agility budget:

- Which transactions with potential suppliers are expected to be important
- Which features (described later) of those transactions are important, with a weighting factor for each
- An agility bogey (or goal) for each instance
- An agility budget

35.5 Your Agility Budget

[How you could spend your budget.]

The budget that you have been given is 25% over the baseline cost of the metal fins. Included in this budget is the cost of changing suppliers from the one planned to supply the metal fins. LandFin is the supplier selected for this job, being the best (in terms of cost, time and quality) only when the metal fin design is considered. They have no experience with composites, so would not be an agile choice. But they are your baseline.

The 25% budget does not include added cost to the product proper; that is considered in the decision by engineering/management in whether to go with it or not. But it does include the cost of having a ready supplier base.

You can spend the money as you wish. Examples of how you may chose to spend your budget:

- Increasing your internal ability to support the change, for example in acquiring specifications related to composites
- As contract termination fees to discontinued suppliers
- As fees to keep suppliers *hot*
- As funding to help suppliers learn/hire consultants or insource skills
- As funding for your cost to transfer skills, processes and equipment to a supplier

35.6 Probabilities Of Change

[The likelihood that things will change, requiring agility in the supplier base.]

Management has consulted with the engineering staff and determined a balance for deciding to go with either of the two options. The composite nozzle option has a cutoff date for when the risk will be engineered out of the system design. That date is 200 days before production. A similar cutoff date of 100 days is given for the composite fins, because it will perturb the overall design of the missile less.

Your job in effect is to design the risk out of the supplier base of making these design changes late in the game.

The planners believe that there is a 20% chance of going with the novel nozzle, and a 50% chance of going with the composite fins.

35.7 Your Alternatives

[Now with a specific supplier choice, what your options are.]

In order to address this problem, you've decided to investigate four alternatives using the agility metrics to determine the one which is most agile (together with other metrics which measure conventional time and cost criteria):

- Alternative #1: Stay with LandFin, and pay them to develop/insource/outsource the needed capability
- Alternative #2: Reselect a single supplier based on agility, and engage with them to support the needed changes
- Alternative #3: Reselect 2 or 3 suppliers based on pure capability, paying all to stay *hot*, and planning to terminate two.
- Alternative #4: Reselect 2 or 3 suppliers based on both capability and agility, and also engage with them to support the needed changes

The practical use of the metrics will be in evaluating candidates for the alternatives, and in evaluating the alternatives themselves, against the company's agility strategy.

	Passive Agility	Active Agility
Single Supplier	1 Go with Landfin and pay them to develop/ insource/outsource the needed capability	2 Reselect a single supplier based on agility, and engage to support the changes
Multiple Suppliers	3 Reselect 2 or 3 based on pure capability, paying all to stay hot and planning to terminate	4 Reselect 2 or 3 based on agility and engage with all to support the needed changes

Figure 35-3:Your Choices

35.8 The Infrastructure

[The first modeling step, decomposing processes according to the Reference Model.]

Part 4, Tool Strategy

Creating and managing a Virtual Enterprise is a matter of creating and managing infrastructure. Your first job is to parse the infrastructure. We've found four major infrastructures:

- Information Infrastructure (supporting communication and language behavior)
- Social/Cultural (nonexplicit processes)
  - Social Laws (hardwired laws of human behavior)
  - Community Cultures (National, class, and ethnic value-driven behavior)
  - Business Culture (Company/VE specific value-driven behavior)
- Legal/Explicit (explicit, non-physical processes)
  - Contracts/Regulations
  - Business Processes
  - Workflow Processes
- Physical (explicit, physical processes)
  - Logistics/Warehousing (material handling)
  - Equipment/Plant
  - Physical Laws

Details of the infrastructures are given elsewhere. The metrics currently focus on the Legal/Rules infrastructure with aspirations to grow into the Social/Cultural infrastructure. The example focuses on the Contracts/Regulations division of the legal infrastructure for these reasons:

- The modeling dynamics or mechanics within the infrastructure are the same regardless of the subarea.
- The contracts area is most closely linked to Social/Cultural mechanics

In the defense domain, we've discovered some interesting mechanisms regarding how the contracting infrastructure (specifically the relationship between law and engineering) works and have traced its history and that of the conflicting tradition in the commercial sector. So results in this area can be traced not only causally but historically.

The contracts subinfrastructure in your company, that part that deals with your relationship to suppliers, is further broken down, for example, into the following kinds of concerns (as well as others):

- Quality Assurance Provisions
- Liability/Benefit Accrual
- Issues Associated with Intellectual Property Development
- How to Insert New Technology
- Disaster Recovery Plan

Each one of these will be handled as an individual, contributing component with metrics that evaluate its agility in the strategic context. At the end, the components will be added using the weighting factors passed down from the strategic planning effort. The resulting metric will only tell you the time and cost associated with change. Those time and cost figures will be added to other, conventional time

and cost metrics which measure each supplier's effectiveness at production. The result will tell you in quantitative terms which is the lowest time and cost.

35.9 Modeling

[A review of the steps in the modeling process.]

The approach requires that the process be modeled. Fortunately, we only model the small fragment of the action that concerns change. It is not necessary to model the entire enterprise to extract the agility information. A large number of modeling or representation techniques can be used, which allows you to use the tools with which you are familiar, or which coordinate well with other analyses.

The process is one which starts with a model and ends with a model, the parametric model which is in fact the metric. Along the way we'll perform four operations:

We'll constrain the models to the areas of the VE that are of concern. We do this primarily because it helps literally to shape the model the way we want. But it also helps in identifying those areas of the VE where missing or incomplete models might exist. Then, we'll constrain the models so that each major process conforms to a communicative act as formally defined in the literature.

The third step is deriving something called a Dooley Graph of each model and counting that graph's main structural features. This process is formal and straightforward and results in a numerical function. In the final step, all of the functions from the small model fragments we've been considering are summed in a weighted manner to yield the agility of the system.

All of these steps can be performed manually, without automated help. But we plan to build tools that support each step of the way, making the process easier for our tactical manager.

35.10 Parsing the Enterprise

[Breaking down the Legal/Explicit infrastructure.]

The metrics described in the example will all come from the Legal/Explicit infrastructure, meaning those processes in the enterprise which are explicit. We'll be creating or abstracting many small models of special processes of interest. The infrastructure breakdown determines how many small models there are and what each one contains. It's important that the models be *clean*, capturing only the information from each perspective of a process.

The first decomposition of the Legal/Rules infrastructure is into three main areas:

- Contracts/Regulations: This includes legal issues of course, formal and informal. External issues are the laws within which the VE operates. Internal issues are the contracts which bind the VE together and to the customer. This collection of models drive the risk/reward system. Models used to define these processes are often different from the others since the processes have different dynamics. Most

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notable is the notion of what is true. In this domain, truth is equated with what is admissible.

- Business Processes: This area concerns the structure of how the business operates. For instance, who reports to whom, who evaluates performance, who certifies certain elements, like engineering processes, are all central to this area. The processes captured here explicitly distribute the risk/reward tokens within the enterprise.
- Workflow Processes: This final component of the infrastructure deals with the actual processes of getting the work done. In manufacturing, it's the collection of value-added operations of the product.

Most activities span all three of the areas. A product component may move through the factory being operated upon, its route and state may be affected by supervisory control (say, an inspector), and it most always has a state that is tracked by a contract space (say, an activity based costing system).

Capturing each of the state changes individually and independently is intuitive and easy to do. But it could in some cases require substantial work to tease these three threads from existing models.

35.11 Identifying Agility Transactions

[An overview of how the metrics are calculated.]

The method depends on the view of an agile system as a collection of dynamically coupled processes. A key concept is the decomposition of the elements, which are coupled into a standard form, and the subsequent analysis of the coupling.

We standardize the decomposition by constraining by infrastructure and communicative acts (which are described below). But we're jumping ahead to explain why. The focus is on the nature of the transactions which couple the standard processes.

That transaction boundary has five features which indicate agility:

- *Distance*: measures the difference between the *handling* of processes on either side of the transaction boundary. If they are similar, changes in one side (assuming a control hierarchy) can be employed at the other. More similar is generally more agile. A contracts example: using the same accounting and legal mechanisms on both sides of the boundary increases agility of that component.
- *Time Delay*: measures the time it takes to complete a token's passing. A token is the item delivered and the payment received in the for-profit case. If the time is short, the coupling is tight and the *messages to change* will be faster. A contracts example: if the compensation accounting can be coupled to a finer granularity of work, it increases the agility of that component.
- *Moveability*: measures the ability to relocate the boundary elsewhere. If the boundary is moveable, it can be adjusted *right* into the supplier, or *left* into the prime, can change granularity or handle a different parsing. A contracts example:

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if the contracts/business boundary can be moved to include some of the prime's responsibilities by the supplier without changing the contract mechanism, it is more agile.

- *Importance*: measures the ratio of the complexity of this transaction to that of the entire enterprise. If the importance is high, the local granularity of the decomposition is large. In a centrally controlled paradigm, this would be more agile; in a paradigm with decentralized control, it would be less so. A contracts example: if one set of terms and conditions covers a large set of possibilities, then the contract is more agile, assuming a conventional prime-controlling paradigm.
- *Frequency*: measures the ability to increase the rate of the transaction. If the boundary's rate of exercise can be increased (within scope) without changing the mechanism, that mechanism is more agile. Contracts example: increasing the quantity of products.

The immediate goal of the process is to identify all of the transactions that contribute to each of the infrastructures. In this example, there are three. Further, we'll characterize, by means we introduce soon, all of the five features. The result will be a matrix of five features by three infrastructure areas. Each cell will have several entries, since each infrastructure area has many processes of interest.

35.12 Communicative Acts

[The metrics are based on communicative acts.]

The idea of prototypical communicative acts is a central concept we use in evaluating each of the model fragments. The idea is an important step in developing an agility function for each of the model fragments. It is based on a well understood theory of communication that has been stable for decades.

The basic idea is that each of the units of behavior of interest in the enterprise fall into one of only a very few--exactly seven--acts. It is possible to form each unit of behavior so that it reflects exactly one of these acts. It will soon become apparent that forming the model in terms of these acts is essential to the evaluative process.

The seven acts are divided into speech acts and non-speech acts. Non-speech acts are constrained to either ship or pay. These constitute the final actions that define the business, transaction boundary. If we were applying the agility metrics to not-for-profit activities (government, universities, combat teams), we'd need to substitute others.

If the transaction boundary is internal to an organization, as most are, then the ship and pay acts may not be the most intuitive. *Ship* is the value added that the unit of behavior in the organization contributes. Pay is the cost of supporting this unit of behavior. Note that activity-based costing philosophies help with this decomposition, but the actual costs are not of interest here.

The remainder of the acts are speech acts. They support the fundamental transactions of *ship* and *pay* which define the transaction boundary. They are of two types: *solicit* and *assert*.

Solicit acts are ***request*** and ***question***. An example of ***request*** is:

"Please send me 50 widgets by next Thursday."

An example ***question*** might be:

"What is your capability to provide widgets?"

Assert acts are ***inform***, ***commit***, and ***refuse***. An example of ***inform*** is

"I don't have 50 widgets."

A ***commit*** statement might be:

"I plan to send you 50 widgets at catalog price by next Thursday."

Refuse is seen in:

"I'm abandoning my commitment to send you 40 widgets at catalog price by next Friday."

Identifying and aggregating units of behavior to match these acts is intuitive and easy. With a little support from a tool or style guide, that aggregation is unique.

35.13 Final Infrastructure Decomposition

[Back to the example now, we look at the legal infrastructure.]

With those concepts briefly introduced, we are ready to return to the scenario. Because it is the most novel, we'll focus on the contract subdivision of the Legal/Explicit infrastructure.

The decomposition to this level is the same no matter what business you are in. But we need to go one level down, and that decomposition varies from sector to sector.

In our missile example, the types of processes that are of relevance include Quality Assurance Provisions as well as others. Of these, we'll focus on contract support for QA in the suppler-to-prime relationship. It is interesting, and, in the case of switching from metal fins to one of the composite alternatives, shows a revolutionary type change in the VE's contracts infrastructure.

35.14 Modeling The Quality Assurance Process

[Within the legal infrastructure, we focus on quality assurance as an example process.]

Fortunately, parsing the infrastructure into these components results in very simple processes. Here, we are only concerned with contract support for QA, not the entire process. In the baseline case, the case where you have a single supplier, LandFin, and are buying the metal fins, your QA is driven from above. From the contracts point of view, the sole purpose of the QA process is to satisfy the customer and indemnify yourself against claims.

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Part 4, Tool Strategy

In the baseline case, you use a conventional (for defense primes) approach: You get a first article from the supplier, you destructively test it, and then you put into place an inspection/certification process that ensures that the supplier is meeting the relevant military specifications. By the terms of your typical defense contract, if you do these two things, you are indemnified from future damages. In this case, you understand how to test the fins and you own the test equipment.

Your source model will record:

- 1. Request for QA items from LandFin
- 2. Receive the first article
- 3. Test the first article
- 4. Accept the design, or
- 5. Reject the design
- 6. In the case of 4, Get the process certification plan (which tests for mil-spec compliance)
- 7. Evaluate the plan for its ability to protect you and satisfy the customer
- 8. Accept the plan, or
- 9. Reject the plan

You'll also model the QA processes of the alternatives from the contracts perspective. But either of the composite options are quite different. Let's say that your company has no experience with composites. In particular, you own no composites test equipment, nor do you have any related test experience. You can specify performance of the composite part, but you have no way of testing it; you'll have to count on the supplier for that. Also, DoD has no relevant specified processes for composites of this type, so you'll have to ask the supplier to guarantee processes.

Note the radical difference here. In the baseline case, all of the contract processes are geared toward indemnifying you through the customer. In any of the alternatives, all of the contract processes are geared to ensuring indemnification through the supplier. This is quite a change.

The alternatives all share the same model, recording:

- 1. Request for indemnification plan
- 2. Receive the plan
- 3. Examine the plan to see whether the guaranteed performance of the product meets your needs, and to ensure that their plan indemnifies you
- 4. Accept the plan, or
- 5. Reject the plan
- In the cases of alternatives #2 and 4, where you have decided to take action in case of a deficiency in the supplier, the model goes on. In these cases, the action would be to help them acquire a competency that makes them capable of indemnifying you. For example, you may loan them money for test equipment, or use search skills to find them a subcontractor to fill their need. The extended model for these cases is:

- 6. In the case of 5, Get help from a third party
- 7. Install the assets, loop to 2

Capturing the information for you was easy because it uses intuitive concepts, doesn't force me to model the entire VE in order to understand contracts, and would have allowed reuse of diverse models.

35.15 Quantizing The Model

[Here's how the metrics are derived.]

The novel approach of the metrics is the idea of topological abstraction which is a category-theoretic idea. Simply explained, this approach is based on the fact that if phenomena are constrained in certain ways in their representation, then substantial information can be obtained by looking at the underlying form of the expression.

A simple example would be in the parsing of sentences, an exercise that we all did in primary school. One can tell a great deal from the parsing diagram without getting into the actual meaning of the sentence. For instance, one can know whether it is a question, a joke, or a command. Especially with methods which are more advanced than the old school sentence-diagramming, one can get a good feel for whether the thoughts expressed are more complex or colorful in one sentence than another. A judgment can be made whether there is a more complex thought behind the sentence. Actually, there's been a substantial amount of work on such structural deductions of constrained representations [GORA92h]; it's Sirius-Beta's specialty.

A truly accurate metric would involve some nonintuitive abstraction that would probably be machine assisted, and this is absolutely required when using the metrics for strategic planning (Virtual Manufacturing simulation). But a quite accurate approximation of *static* agility can be made using manual, intuitive methods. The trick is to reduce the model to a Dooley Graph. This graph essentially captures the complexity of the transactions involved.

The Dooley Graph consists of nodes and links, and looks much like a simple translation of the model with the parties as the nodes and the communicative acts as the links. It differs in having multiple *editions* of the parties as multiple nodes. When a new conversation is initiated, a new edition of the initiating party is created, with links showing the speech acts as appropriate.

The result is a simple diagram which reveals a surprising amount of information about the transaction mechanisms, information that tells us all we need to know about the important elements of changing from one type of transaction, say, our base case of customer indemnification for metal fins, to one of our alternatives which relies on supplier indemnification.

The Dooley Graph for the base case breaks your company into two parties, the contracts department, and the engineering department, which for contracts' sake is a different entity, and each of these has two conversations. It also breaks down the supplier into two parts, because of the conversations.

35.16 The Graphs

[Graphs for the example process.]

The graph for the baseline case has six nodes arranged this way:

- Contracts (Node AC1) gets and receives the first article from the Supplier, LandFin (B1)
- Contracts (AC1) has Engineering (AE1) test and report on the first article
- Contracts (AC1) notifies LandFin (B2) that the design is acceptable
- LandFin (B2) accepts Engineering (AE2) in-house to monitor mil-spec conformance
- LandFin (B2) delivers an acceptable plan to Contracts (AC2)

The graph for alternatives #2 and 4 has five nodes arranged thus:

- Contracts (AC1) asks Supplier (B1) for an acceptable design and indemnification plan
- Contracts (AC1) has Engineering (AE1) evaluate and report on the plan and design
- Contracts (AC1) sees a discrepancy in the plan and goes to another company (C1) to supplement the plan
- That company (C1) installs the missing competency to the supplier (B2)
- The supplier (B2) reports back to contracts (AC1) with an acceptable plan

If a node has two links, it is called a two-node, and so on. If a link is part of a two-link loop, then it is part of what is termed a two-loop. Given this simple breakdown, the first graph has one 1-node; three 2-nodes; and two 3-nodes; two 1-loops; and four 2-loops. The second graph has four 2-nodes; and one 4-node; and two 2-loops; and one 3-loop.

These simple topological features are all that is required to extract our quantitative information about the five features which capture agility.

35.17 Transaction Features

[The example's transaction numbers.]

We believe that transactions in the enterprise are the fundamental engine of doing work. We further believe that these five features completely yet sparsely (most efficiently) characterize agility, the ability to respond to change. Characteristics of the graphs give a satisfactory quantitative metric for these features:

- *Distance*: The (weighted) number of nodes. The weighting is by the power of each node (the number of two-node is raised to the power of two), so the distance (from zero) of the base case is 11+22+22+22+33+33=67. The distance (from zero) of alternatives #2 and 4 is 22+22+22+22+44=272. The relative distance between them is 272-67=205. The time and cost of adapting from a distance of, say 100, is less in a predictable way than the time on cost of adapting a distance of 205.

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- *Time Delay*: The (weighted) total number of loops. The weighting is similarly by the power of the loops, so the delay (from zero) of the base case is 11+11+22+22+22+22=18. The delay of alternatives #2 and 4 (from zero) is 22+22+33=35. The relative time delay is 17. A greater number is correlated with a greater sum of time and cost.
- *Moveability*: This metric is a topology match between the two graphs and measures the structural difference of the support for communication. It is calculated as the ratio of nodes that match to baseline nodes. The baseline case has one 1-node, three 2-nodes, and two 3-nodes. Alternatives #2 and 4 have four 2-nodes and one 4-node. Of these, three of the six nodes can find matches in the base case, so the moveability metric is 50(%). It's a crude topological measure but very effective: a greater number indicates a greater match and a lowered time and cost to adjust.
- *Importance*: The ratio of nodes to the total number of nodes (weighted sum) in the contracts subinfrastructure for the entire Virtual Enterprise (in this case, the supplier chain), normalized by 10,000. Suppose that the total number of nodes in that area is 13,669 for the base case and 8,085 for the alternatives. Then the importance of our example in the base case is 67/13,669x10,000=49, and that of the alternatives 272/8,085x10,000=336, a much higher importance, the difference being 287. The greater the difference either way the greater the time and cost of change.
- *Frequency*: Is calculated in the same way as importance except using weighted loops. Employing the same arithmetic, the frequency distance metric between the two is 1,554, supposing that the base case's loop sum are 4,890, and that of the alternatives is 220. The greater this number, the greater the time and cost of change.

35.18 Summing The Metrics

[How the component numbers are added.]

We've given an example of deriving metrics for one of the small components into which we've decomposed the situation. You'll have many of these for each of the three Legal/Explicit infrastructure domains under consideration. These will be well-behaved arithmetically, and we want to add them according to the importance of that component to the enterprise. For example, it may be that the QA contracting area is expected to carry three times as much weight in computing the cost of change than, say, the component related to retraining document editors.

This relative weighting is one of three important pieces of information that the strategic planners passed to you at the beginning of this exercise. They derived that information from simulation exercises using dynamic forms of the same metrics. The three insights they passed to you were:

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- The relative importance among the components of the enterprise
- The breakdown of time and cost. You'll have created graphs which relate the five features to relative agility. Your planners will correlate the function you

derive to the breakdown between time and cost, because that relationship is a matter of strategic priorities.

- Finally, they'll have given you the probabilities to assign to each of the alternatives so that you can weight how important agility for the composite fins is compared to the metal fins and the composite nozzle. We've already noted that those probabilities are: 20% for the nozzle, 50% for the composite fins, and 30% for the metal fins in absolute terms, but each of these probabilities is time-related. Everything changes, for instance, once the deadline for selecting the nozzle passes at minus 200 days.

Alternatively, you can get the same information from a large robust Case Base on collected calibrated agility case studies. The Agility Forum has such a case base planned.

You are now able to perform several simple arithmetic calculations:

- You apply the time and cost functions to break your many component numbers into their time and cost equivalents
- You use the weighting function to sum all of the components for each alternative

On those totaled time and cost curves, you locate your agility bogey. We use the horizontal axis for this.

What you have now is a total time and cost of change for each of the four alternatives, multiplied by however many candidate companies you have (combinations of companies in the cases of alternatives #3 and 4). But you are not finished yet! It's not enough to go with the candidates and alternatives that offer the lowest cost of change if their product cost is high. So you now get to add your agility time and cost of change with separately derived time and cost metrics of their basic products and services.

And, at last, you weight the costs by the 20, 30 and 50% weighting for possibilities that you are given and you have indications for the lowest cost design of a supplier chain under the engineered conditions of change.

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36 Case Study Setup

[Here we describe the case study.]

We developed the practical (and the alternate) scenario to better understand the target application of the sponsors, namely the defense manufacturing enterprise, specifically in aerospace systems. We also needed a context for a *case study*.

Our project did not call for a *pilot project* in this phase, one in which tens of millions hang in the balance, ideally with a calibrating base case. But we did want to walk through a real situation to test the ideas. During the course of the project, we were reviewed by many enterprises, who reported back high confidence that the method was valid, that is to say, the metrics would *work*. Also reported back was confidence in the merits, the financial benefits, of *agility* in certain common situations.

Where we were questioned was on the cost of applying the metrics. Managers have been burned before: they spend so much effort and resources on *determining* what they should do that they cannot afford to do it. We would have to determine how much this would cost in a typical scenario. In fact, if the cost were not manageable, the method itself would be too ponderous and could not be used itself agily.

So we set up a case study with the following characteristics:

- focused on the supply chain, assuming practices current or possible without presuming unrealistic change in acquisition law;
- centered on problems of a real tactical missile manufacturer as defined by the DARPA sponsored Affordable Multi Missile Manufacturing (AM3) program;
- audited by an third party experienced in enterprise engineering, the Aerospace Agile Manufacturing Research Center; and
- devised to evaluate the *cost* of applying the metrics in a practical case.

36.1 A Component in the Case Study

[We assume a High Concept description of a missile.]

Did Morita have it right? Is Hollywood an exemplar of the new way of building organizations which are especially attuned to customer's needs, even more deeply than they themselves know? Is this extractable from the exotic movie sector and applicable to the primarily high-value manufacturing domains which concern us in the agility community? Is this agility?

With due regard to the limits of pressing analogies too far, We're inclined to think so, and have framed our Defense Case Study in the context of a (fictitious) High Concept enterprise.

The chain of logic/chain of events we tentatively propose to follow is:

- Start with a succinct problem statement, a *High Concept* for a missile, if you will.
- Use the AVE Reference Model to identify agents that result from the High Concept. To some extent, we've explored these first two steps in our strawman. But

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we'll go back and define a workable High Concept and test whether agents and model cells follow as a matter of engineering principle as opposed to art. We'll apply techniques used in the movie AVE where applicable.

- Decompose each cell into a number of transactions among agents. This is the meat of the Case Study; we hope to determine how *costly* it is to evaluate agility in a typical case, and believe this step represents the greatest cost and greatest unknown. We may be translating from a model which has the appropriate information; we may be supplementing the model to make it adequate; or we may have to start virtually from scratch. In this case, we'll probably bypass a general modeling method, and just directly populate our simple utterance table.
- These utterances will each be expressible in the *acton* form that we've devised under the Situation Theory work from our two (so far) BASTs. The equation form will be:
    - The collection of actons which describe the interactions (utterances) that constitute a cell in the AVE model-- then those actons *support* the situation of the cell. Collectively, the actons of all the cells support the situation which is the High Concept; this is the same as saying that the situations of the cells (meaning processes of partners in the VE) support the High Concept (meaning the specific, deep opportunity in the customer space being addressed).

      In devising the Situation Theoretic logic, we hope to extract parameters, variables and constants with guidance from our movie exemplar if we can keep them engaged. (This step is dependent on cooperation from the AM3 program office.) When tools are built, such as the Pomegranate example we are sketching out, they'll leverage this logic.
- Then, of course, the agility metrics will be calculated, at both the system level and for each individual cell. As noted in the Tool Strategy, we're putting private funding into creating a probably freeware openDoc (also known as Live Objects) container for visualizing these results.
- Finally, the system-level agility metric will be applied at the High Concept level to evaluate the relative time and costs of supporting the High Concept by those agents and strategies.

36.2 Defense HC Issues

[A few issues related to defense high concepts.]

Currently, missile product definition statements are pretty frozen and quantitative by the time they get to the prime, who relatively late in the game responds by assembling a team/supply chain. The description is of the form:

"give us a thing that goes this far, this fast, is *this* size, shape and weight, goes boom in *this* way, and costs *so* much."

A High Concept version would be of the type:

"give us the capability to perform *this* mission, or counter *this*

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threat."

An agile-requiring High Concept would add a *range* of possible missions or threats. Because it's unrealistic to expect a *pure* High Concept, we'll devise a hybrid: given a specific missile (and it's supply chain) how much in time and cost will it take to engineer (or adapt) a supply chain to cover a given range of missions or threats.

36.3 Goals

[What we hope to accomplish in the case study.]

The central purpose of the project is to devise quantitative, formal metrics that an enterprise can use in evaluating the effectiveness of processes and agents in devising appropriate agility strategies. We have those metrics, in a simple first-order form, and a more complex but capable form. A tool strategy has been devised which includes simple, low-cost evaluation techniques if the process is well modeled.

(The tool strategy is based on bridging the gap between this new idea of dynamic coupling among processes and existing business/process modeling tools to feed simple and complex numerical business planning models. We propose to do so by relying on the formal basis of the metrics as mathematical features of logical parsings of process models or their associated agents.)

This leaves us with a situation where we know roughly the benefits of agility and the effectiveness of the metrics. But we do not know the *cost* of getting information from the Virtual Enterprise into the evaluation process.

Therefore, the primary purpose of the Case Study is to evaluate the cost of getting sufficient information about yourself, your potential partners, the environment and various strategies. If this cost is high, agility becomes problematic, regardless of benefits. Our application scenario is fairly mundane: a conventional supply chain (Type 3 AVE), but further restricted from novel practices by focusing on defense manufacturing. This is seen as a defining domain: if the costs of evaluating agility in conventional, relatively staid environments is low, it should be lower as agility strategies increase.

Because running a test involves walking through all the major steps, a secondary purpose of the study is to understand how an agility strategy is formed, and what processes are involved. We expect that all steps will have to be considered, but the major attention will be on identifying the key processes involved, why and how they affect each other and the VE.

36.4 Application Domain

[Characteristics of the scenario.]

The Case Study looks at agility in building and maintaining a Supply Chain in the U. S. tactical missile community. This domain has the following characteristics, which would imply a need for agility:

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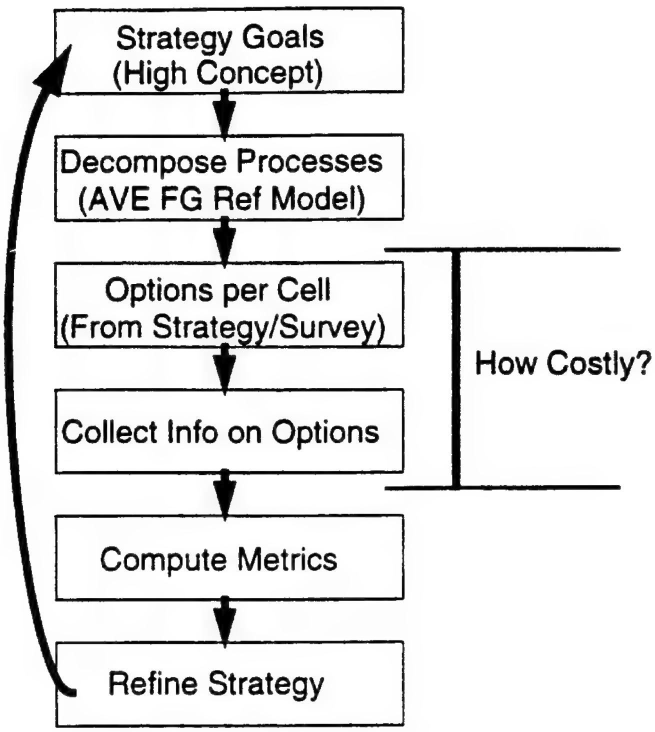


Figure 36-1:How Costly Would the Modeling Be?

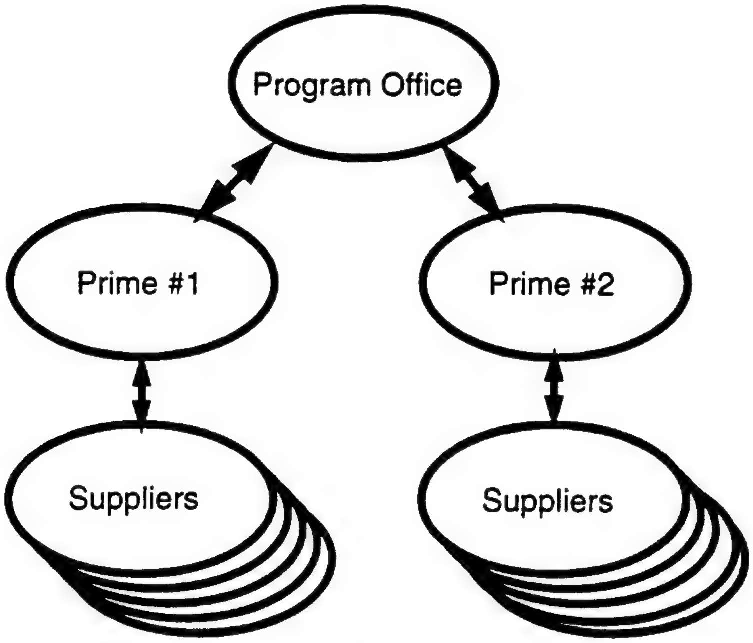
- The prime contractors are consolidating and sloughing off capability, creating VEs within the primes at some level; investment cycles (changerate) within the primes are being disrupted. So multiple products must be created with the same assets.
- The product is complex with a very high technology component; changerate (rate of change) of basic technologies, in both products and processes) is high and increasing.
- The *Supply Chain* adds a significant percentage of the product's value, with many niches of product and process specialization; that supply base is becoming less rich over time.
- The customers are changing: where the U. S. military used to be the primary customer, now foreign sales are becoming more important.
- More variants and derivatives are required; product/customer expectation changerate is increasing. The missions are more unknown.
- To an increasing degree, the product must be integrated into larger systems whose basic designs and integration strategies are not under the control of the prime but which are jointly owned by several peer primes and the customers.

In addition, the domain has the following two characteristics which may be unique, and which may make the Case Study manageable:

- The acquisition laws and regulations which govern the customer to prime, and prime to subcontractor relationships are different, more limiting, than those in

the civil sector. Competitive pressure exists, but the mechanics are different than conventional free market forces.

♦The defense manufacturing base in general is often managed as a *strategic* asset. The customer, DoD, performs roles as conventional consumer of products, specifier (often designer) of products, often controller of work breakdown, processes and indemnification, and as occasional manager of strategic design and production assets.



Two supply chains: Conventional chain (agility benefits the prime); DoD chain (agility benefits the nation)

Figure 36-2:In DoD, the Customer is Often the Integrator of the Supply Chain

36.5 Participants

[We work with a real missile prime, audited by the Automation and Robotics Research Institute.]

The Case Study is designed to support the goals of the DARPA-sponsored project for Affordable MultiMissile Manufacturing (AM^3). This project focuses primarily on the first characteristic noted above: the same assets need to be applied to multiple missile designs to effect cost savings. In order to do this properly, AM^3 addresses all of the other noted issues.

We focus on the missile Supply Chain. There are two Supply Chain views. The first is conventional: an AM^3 prime and its subs. The suppliers themselves will not be interviewed in the Case Study. In this view, we will focus on elements common across defense and civil sectors.

The other Supply Chain view has the DoD at the top. Here, two primes supply components that the customer integrates as if it were in many ways the prime.

This is unique to the defense sector. In this case, the AM³ prime and another large missile contractor are the two primes.

Although the Case Study is not on a specific system, there is a real case in which these two are collaborating primes. supplies a missile and the second missile prime supplies the submunition. The submunition is installed into the missile by the AM³ prime, but it is specified and acquired by the DoD, provided as Government Furnished Equipment.

Sirius-Beta will lead the effort. The Automation and Robotics Research Institute (ARRI) of the University of Texas - Arlington will assist.ARRI is a National Science Foundation Agile Manufacturing Research Center.

Creating an agility strategy and evaluating options against that strategy involve some steps that cut new ground. The Agile Virtual Enterprise Focus Group, sponsored by the Agility Forum, is an important review and brainstorming body. The AVE Group is supplemented by the Metrics email list and web site (also administered by the Agility Forum.

36.6 Strategy Identification

[The agility strategies one might consider]

Agility is the ability to respond well to unexpected change. Agility is obviously beneficial in a domain like our target domain, but devising an agility strategy is non-trivial:

- Agility usually costs money which could be put toward other strategic investments; relationships of agility to other tactics needs to be evaluated
- Agility in some dimensions counters agility in others, so the general shape and likelihood of the threat needs to be identified
- An agility strategy needs to work in conjunction with other elements of strategies within the VE (market dominance, versus immediate profitability for instance)
- An agility strategy needs to leverage natural strengths in the current and possible partners' collective and individual core competencies and management philosophies

As a result, an agility strategy cannot be prefabricated outside of the specific context as less promising techniques can, such as lean. One cannot escape the fact that agility is a strategic weapon and cannot be crystallized outside of the individual strategic context. For our Case Study, we'll follow what we believe will be a common playbook:

- Evaluate the nature of the change to which we want our missile Supply Chain to respond, in other words, the kind of agility that we want engineered into our VE
- Identify a few strategies that may provide an agile response. For the Case Study, this will be an intuitive, ad hoc process guided by the community. It is this process for which outside guidance is sought, both for the example case, and for general principles for others. However, elsewhere we have sketched out a tool

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strategy that could guide this process.

These strategies will vary according to:

- Different business models for the VE
- Different agility processes and agents that support the model
- Different partners (in this case, suppliers) that have better or worse capabilities in those areas

As mentioned, we'll look at two Supply Chains. Both will consider the same threat of change, as listed above. But the emphasis will be on combining design/production assets for many existing missiles (which should lower some costs without agility) at the same time lowering costs associated with introducing technology for upgrades; variants; and future (perhaps modular) derivations. But the two Supply Chains will weight values differently:

- One will be a conventional Supply Chain headed by a prime (The AM³ prime). Presumably, its primary values to be supported by agility will to continue as a healthy entity (both as a company and a Supply Chain) through making profit, preserving/building core competencies, and satisfying the customer (DoD).
- The other is a Supply Chain starting with DoD, including the AM³ prime, the second prime and their lower-tier Supply Chains. It's goals will differ, looking for agility to deliver high quality missiles at acceptable cost while preserving a robust capability to respond similarly in the future. It's customers are the war fighter and Congress (representing the Nation) in some often conflicting mix which we won't examine.

The presumption is that there should be substantial overlap between these two goal sets; maximizing the overlap will be an additional factor in evaluating agility strategies.

36.7 Suggested Initial Constraints

[Here we narrow down the scope of what we'll model.]

Fortunately the constraints and dependencies of the models, as well as the focused goals of the missile enterprise, narrow the choices of agility strategies, and consequently cells in the models to investigate. We exclude the Social/Cultural Infrastructure. We don't know how to deal with it, and it is not directly in the AM³ scope. Let's readily admit that this makes the case study less effective than it could be. (The Work and Technology Institute anchors our projected future work in this regard.)

Under normal conditions, the strategy would be measured under a complex mix of results, each with its own metric. That mix would include near-term profitability, and long-term profitability (stockholder value, market share, goodwill, capable workforce/increased core competencies). For the sake of argument and simplicity. lets assume that the *lesser* supplier chain The prime/sub chain) cares only about near term profitability. Similarly, we simplify the goals of the *larger* Supply Chain (DoD, through primes to Supply Chain) are a straightforward measure of lowest

cost product (missile systems) for the next 20 years. Extending the measure for two decades includes considerations of responsiveness and strategic capability.

The scenarios are wholly fictitious, invented for the sake of simplifying and focusing the case study. No relationship to companies or projects should be drawn. the AM³ prime and the second prime are providing typical process examples only; there is no relationship between those firms and the fictitious examples we've created.

36.7.1 Simplifying the Model

[Rationale for ignoring large areas of the Reference Model.]

As a first order of scoping, we suggest that we reduce the model to something manageable: the full Reference Model has a potentially very large number of cells. The five phases of the life cycle only give us 26 subphases. But the infrastructure (which is a decomposition of the fabric of the VE) has an arbitrarily large number. For illustration above, we note the five most important for each of the subinfrastructures. That alone, yields over 1500 cells. But we know that only a few cells bear on any given agility strategy. So as a first step, we suggest temporarily setting aside areas of the model that are unimportant to the Case Study.

We've already noted that we set aside two of the four infrastructures, Social/Cultural and Information. In addition, we'll set aside considerations of Physical Laws. There are some interesting ways in which physical laws bear on the subset of agility called flexible manufacturing, especially dealing with composites, exotic materials, and electronic devices. But they are uninteresting in the context of agility, since those processes are not ordinarily delegated to the Supply Chain. So we set aside that division of the Physical Infrastructure.

We'll also set aside the subinfrastructure of equipment; and we do this more deliberately. There are two reasons: agility in the Supply Chain has primarily been found to be dominated by legal problems, cultural mismatch, and lack of process integration. Agility of equipment is pretty far down in the food chain. We've mentioned this above, and submit it as an example of how higher level infrastructure can govern those at a lower level. The second reason is a matter of focus. The novelty of agility, what makes it different and new is often obscured. Many believe it has to do with speed, or flexibility, and a prevailing, but misguided definition focuses on how quickly equipment can be reconfigured. Our setting aside of equipment all together helps focus on more important dynamics.

This means that we will deal with four subinfrastructures: (using our numbering scheme from above) A. B, C and D. Each of these has been expanded into five process areas. We suggest that we select the one from each which is most apt to anchor an agility strategy, giving us four columns of interest (out of the 60 we started with).

For example, consider Group A, *Business Processes*. We suggest that of the five listed, *A.e Depth of Customer Relationships*, is the one which we'd like to highlight as being the most likely among its siblings to anchor, or be a major component in

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a missile Supply Chain agility strategy. In evaluating among these five, you have to remember the whole hierarchy. That is: the group of five all deal with explicit business processes: processes that have been engineered, are understood to great extent; and deal with how the business operates. This includes who is responsible for what, who reports to whom, who makes decisions about what, and what criteria they use.

All of these are important to a healthy enterprise in general; any of these could be important in an agility strategy. However some are less important to agility or to the defense missile business, for example, *A. d Work Scheduling*. Now remember, we're not talking about the whole beast here, there's an area (we've called C) that deals with the area proper. This is just the business process support for work scheduling. In the defense arena, there's little control that the prime has in innovating in this area; the controlling processes are driven by the customer through contractual and funding restrictions.

A similar disqualifying property can be found in the business processes for *Supervising Quality*. There's not much flexibility an owner of a defense Supply Chain has over those business processes. A case can be made that there is some opportunity to work with Risk/Reward strategies in the Supply Chain, and that those affect agility. But we believe that contract provisions are the governing dynamics and not business practices, so we bump Risk/Reward from this list, and rank it high among the candidates for B.

As the high value component among these five, we select business processes to support *A. e Depth of Customer Relations*. This covers procedures to ensure that appropriate elements within the VE are exposed to, understand and respond to needs coming from the customer. This is clearly at the root of the need for missile agility: the need to respond at low cost to product/process technology, mission, and Supply Chain infrastructure changes. And it is an area over which missile primes (and the DoD) has the option to innovate; change in these business practices is happening regardless of agility, sometimes in an uncontrolled fashion.

So as our key process from A, we select A.d. In a similar way, we select one from each of the other four. From Group B, the group dealing with laws, contracts and regulations, we select *B. b. Risk/Reward Contracts*, as we note above. Within the AVE, partners can be expected to respond well if the risks and rewards are engineered for agility.

C. c. Monitoring and Adjusting the Work Breakdown Structure is the third lead category. This is the process that decides and reassigns who in the VE does what. In the defense enterprise, the WBS is a particularly unagile process control practice as it puts the customer in control of the processes.

From the Logistics/Warehousing group, the lead activity is *D. a. VE Human Collaboration*. This is the infrastructure component that supports how individuals communicate (and otherwise interact). Since agility revolves around trusted agents, and the influence of such agents is determined by face time, this is an essential infrastructure.

36.7.2 Life Cycle Selections

[Rationale for narrowing down to a few life cycle points.]

In a similar way, we simplify the Case Study by choosing one division from each of the five major Life Cycle divisions. From *1. Opportunity Identification*, we select *1.3 Targeted Market*: This is a process of active discovery and engagement with the potential user, more suited to the missile community than the other, more passive functions in this group.

From *2. Partner Selection*, we'll focus on *2.3 Partner Search* since we'll assume that there is no substantial prequalification strategy or historical record of performance in unexperienced processes. *3.6 Risk/Reward Strategies* is the key process from group 3, for reasons already argued above. In this case, we're talking about a step in forming the VE, based on the process of determining the approach to risk and reward. In the infrastructure, we're talking about the legal scaffolding build to support such a strategy.

Group 4, *VE Operation* yields *4.1 Performance Metrics* as the primary target. These are the measures used in operation to determine that each partner is doing its job. We target this area because in the defense establishment, it was often the case that the customer intruded into this monitoring process, for example by supplying auditors and setting specifications. Alternatives could yield greater agility. Finally, we settle on *Identifying the Need to Change*, process 1 of group 5. The focus on this is a direct result of recent AVE Focus Group attention on trusted agents. An element of the trust is confidence in the ability to recognize the need for change in the VE.

	A.e Depth of Customer Relations	B.b Risk/Reward Contracts	C.c Work Breakdown Structure	D.a Human Collaboration
1.3 Targeted Market				
2.3 Partner Search				
3.6 Risk/Reward Strategies				

Table 36-1: The Focus Cells for the Aerospace Prime

	A.e Depth of Customer Relations	B.b Risk/Reward Contracts	C.c Work Breakdown Structure	D.a Human Collaboration
4.1 Performance Metrics				
5.1 Identify Need for Change				

Table 36-1: The Focus Cells for the Aerospace Prime

36.7.3 Agility Strategies

[Four different strategies that may be pursued, with example processes.]

We've abstracted out some high value elements of our model for the sake of the Case Study. Now we have four infrastructure columns:

- A. e Depth of Customer Relations
- B. b. Risk/Reward Contracts
- C. c. Monitoring and Adjusting the Work Breakdown Structure
- D. a. VE Human Collaboration

And five Life Cycle processes:

- 1.3 Targeted Market
- 2.3 Partner Search
- 3.6 Risk/Reward Strategies
- 4.1 Performance Metrics
- 5.1 Identifying the Need to Change

A total of twenty, high value cells results. The meat of the Case Study is to investigate how difficult, how costly it is to discover sufficient information about each of those twenty cells to allow us to compute our agility metrics (for each alternative for the cell). In doing so, we'll be guided by the following strawman agility strategies. We repeat, the strategies are wholly synthetic, unrelated to actual strategies within the second prime and the AM^3 prime.

36.7.3.1 DoD's Agility Strategy 1 (I)

Let's suppose that DoD wants to lower the cost of missiles, and it has determined that: high costs are due to specialization. A major symptom is the one missile type, one plant/design team/Supply Chain problem that is apparent. But underlying this is the high cost of moving across business practice boundaries once a project is rolling, affecting the ability to mix Supply Chain expertise and processes. This also prevents DoD from inserting technology into existing products for upgrades, variants and special editions.

DoD might pursue an agility strategy that builds a Supply Chain that has trusted, empowered agents in key positions. These agents are particularly integrated into DoD's systems for determining need, or making cost/performance trade-offs. They would be able to bring information to the table about the need to adapt processes and the cost of adaptation.

This is a specific agility strategy that DoD as the owner of a Supply Chain might devise. A way to support this strategy would be to focus on cell A. e (Business Practice Infrastructure to Support Depth of Customer Relations in the Supply Chain) and 5.1 (Identifying the Need to Reconfigure the Supply Chain). This is the set of processes which establishes trusted agents for change by both providing them with insights/feedback to the customer's needs and the wisdom/ability to make appropriate changes in the Supply Chain.

You could put together a support strategy in which these cells that dominate in their support:

- A.e/ 4.1: Business practice infrastructure that bases the way the Supply Chain is measured in its performance on how well the listen to and respond to the needs of DoD.
- B.b/ 3.6: Contractual infrastructure that supports the above by building appropriate risk and reward strategies into the Supply Chain
- C.c/1.3: Infrastructure which identifies the mapping of processes in the Supply Chain to specific product goals in DoD.
- D.a/2.3: Infrastructure which provides for sufficient collaboration among agents in the existing and potential Supply Chain.

36.7.3.2 DoD's Agility Strategy 2 (II)

Alternatively, DoD may wish to optimize the Supply Chain to address a specific shortcoming in its contracting practices that has hampered agility (and had other deleterious effects). Weapons In general have very high performance requirements. In the past, DoD has intrusively monitored the performer and the process to assure high quality in this regard. But DoD could look for other ways of managing this performance equation.

So DoD might be interested in an agility strategy that lets the Supply Chain flexibly work out who does what, so long as there are adequate performance metrics

that travel with the work package, and those performance metrics are directly linked to system-level performance goals monitored and changed by the customer.

So instead of having to look into every component process when a system-level specification is examined, the supply-chain is self-correcting to parcel out the work and measure performers appropriately.

The basic cell in this case is C.c/4.1, infrastructure which parses the complex product, the tasks that need to be performed, and the measures that guarantee quality to respond to DoD's needs without requiring DoD's intervention. This strategy would be supported by:

- A.e/3.6: Business practice infrastructure that ties how risks and rewards are monitored to directly support DoD's needs for the system.
- B.b/5.1: Contract clauses that rewards suppliers who recognize and instigate change that benefits DoD, but adversely impacts their conventional business role.
- C.c/2.3: Infrastructure which identifies (and perhaps prequalifies) the skills and qualities needed in suppliers to support this agility strategy.
- D.a/1.3: Infrastructure which supports a continuous collaborative structure between the key elements within the Supply Chain and the DoD customer to assure that there is a good mapping from the DoD's system-level performance goals to the detailed workpackage measures.

36.7.3.3 Prime's Strategy 1 (III)

Alternatively or coincidentally, the prime contractor will have need for agility strategies which benefits it as a business. We'll explore two examples of this.

Suppose that the prime, missile contractor understands that essentially all new missile business will be based on current designs in some way. That means extensions of current processes and Supply Chains. Also suppose that their fasted growing areas of opportunity are foreign sales, and each foreign customer has some special tweak it needs.

You want a supplier chain that is built to agily respond to this large class of different and changing opportunities as a simple business matter.

This strategy will be built on cell B.b/1.3, which concerns contractual infrastructure support within the Supply Chain so that each supplier is rewarded for helping you identify and address opportunities by modifying/updating internal processes. The supplier may be rewarded even if the opportunity doesn't mention conventional business sense.

Note that this is different than what we noted above, where suppliers get rewarded for benefiting the (existing) customer. (Here agility benefits the prime over a customer if there is a conflict.)

In addition to the primary cell, a strategy along these lines might be supported by:

- A.e/2.3: Business practice infrastructure to continually identify partners who

can help identify and evaluate opportunities by understanding (potential) customers

- B.b/4.1: Contractual infrastructure which harmonizes performance metrics with new business rewards, thus combining agile new business identification with agile manufacturing.
- C.c/3.6: A work breakdown process that gives each partner reward for seeking new opportunities, even those quite different from the current product type.
- D.a/5.1: Infrastructure that builds a team among key agents in the Supply Chain to share intelligence on and collaborate to reach new opportunities.

36.7.3.4 Prime's Strategy 2 (IV)

Finally, another different example could be described among the many that a prime may pursue. This one relies on D.a/3.6 to set up a collaborative infrastructure so that trust is built among the key players among the partners. The rewards benefit the players in a more self-organizing way than the example above. There, the Supply Chain is engineered to benefit the prime. Here, the partnership is engineered to help each member (including the prime). Since this is a opportunity-seeking strategy, rather than a partner-seeking one, it tends to a Type 4.

This agility strategy is supported by:

- A.e/1.3: Business practices that encourage players deep in the Supply Base to probe the market, alert for opportunities for the VE, perhaps representing same.
- B.b/2.3: Contract support for a partner to benefit if it finds a way to identify new partners, even competitors, if it will bring the aggregate closer to new, good business.
- C.c/5.1: Provision for a partner in the Supply Chain who is not biased to the prime, and who equally represents all of the partners in seeking new opportunities. This partner presumably does nothing else.
- D.a/4.1: Operating metrics which track and reward the quality of support to sustaining the VE above and beyond merely producing goods and services.

36.8 Examining the Cells

[Summarizing the strategies and focus cells.]

To summarize, we have identified four example agility strategies, each with a different set of goals, but all using general assumptions of the missile community. Two benefit DoD, as head of a Supply Chain, and two provide presumably slightly different benefit to a missile prime. These are briefly:

- I. Lowering the cost of missiles by relaxing the costs of adjusting the Supply Chain to respond to change in technology or requirements.
- II. Lowering the costs of missiles by decentralizing the monitoring of product workpackage processes.
- III. Responding to new foreign and derivative US opportunities by changing/

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extending core competencies within the Supply Chain.

IV. Responding to new foreign and derivative US opportunities by leveraging customer-inspired enhanced process improvements by the Supply Chain functioning as a *bidding collective*.

The tentative plan is for the second prime to help us examine the cost of evaluating the cells related to the DoD strategies, and for the AM^3 prime to help with those related to the prime.

37 Case Study Questionnaire

[This section simply repeats much of the questionnaire initially given to the prime and a number of cooperating firms.]

37.1 Background

[Just the short version is reproduced here.]

This section reproduces the short version of the questionnaire that was used in the target aerospace prime. It was also widely circulated via the web to other firms. Those other, voluntary responses provided validating information for the conclusions we reached.

37.1.1 Larger Context

[As background, the approach is reviewed.]

The Case Study focuses on one step in a several-step process an enterprise might employ in engineering an agile system.

1) *Identifying the threat*. An agility strategy depends on what type of unexpected change you intend to counter. Agility in one direction may not contribute, may even counteract, agility in another. While not in the MAVE project's scope, we've also studied how one sector, the movie industry, tracks trends to extrapolate change.

An example threat for a DoD acquisition manager would be to lower the cost of a spectrum of future variants of existing missiles without knowing much about what new technologies will be available, or mew mission profiles may appear. Perhaps the general shape of the change is known. From a missile prime contractor's perspective, this defines a market opportunity.

2) *Devising a high level strategy*. Decisionmakers responsible for the VE will strategize on the bet approach to take. In the probably better cases, each strategic response will be tailored to the stimulus rather than simply being inherited, for example from the prime's global strategy.

Just one example among many high level strategies may be to outsource all but a few key processes, having a spectrum of subcontractor possibilities from standby suppliers, prequalified suppliers and have an open search-and-bond process for new suppliers. Further, you may have operations controlled by management teams from all partners as well as representatives of the customer. But many other strategies may apply.

3) *Looking at specific processes*. Having a strawman high level strategy, you'll need to evaluate it and or implement it through a number of low-level, process-oriented tactics. Implementing the strategy will focus on novelty and/or excellence in a few specific processes specific to both a prime (VE organizer) and the suppliers (partners). You will be faced with different combinations of processes which can implement the strategy.

4) *Selecting specific processes* to implement the strategy by evaluating the rela-

tive cost (in time and dollars) of each process and process combination to provide you the type and level of agility required.

5) *Looping back* to see if information about the costs of the selected strategy and newly appearing alternatives change your presumptions of your agility strategy (loop to step 2) or your understanding of the threat or opportunity (loop to step 1).

The MAVE project, and the Case Study, is focused exclusively on tools and technologies for *step 4*, where agility metrics are derived from specific detailed processes. These processes can be either candidates for an agility strategy, or your current agility strategy which is under review.

However, the MAVE project has looked at tools for the other steps as well. For *step 1 and 2*, to initially speculate on the shape of the threat/opportunity and response, Sandia National Labs, The Automation and Robotics Research Institute, Sirius-Beta and the AVE Focus Group developed a structured controversy brainstorming method which seems to be effective. For step 3, the AVE Focus Group's Reference Model has been developed. This is outlined below. The metrics depend on this breakdown. Also, a specific prototype tool, Pomegranate, is being fleshed out to aid in the evaluation of processes and the exploration of agile alternatives.

The looping back of step 5 could be done in a few ways. One intent may be to use system-level agility insights to interact with other conventional metrics (product cost, response time, appropriate customer-driven quality). Mashed Potatoes is the tool which is being prototyped for this need. Users will be planners with existing skills. A spreadsheet-like format is used, relying on the AVE Model.

But you may want to loop back using a tool which looks for patterns in past cases or stored simulations. New skills would be required for such a tool. Turnip is an example we've prototyped. A document on the tool strategy is at the web site.

For the case study, we assume that the situation is one of primes looking to maximize new opportunities by engineering an agile supply chain, managing that agility (as well as the supply chain of course) and refining internal core competencies.

37.1.2 The AVE Focus Group Reference Model

[The Reference Model is reviewed.]

The questionnaire references a model developed by the Agile Virtual Enterprise Focus Group, created with the intent of providing a best parsing of the processes and components of a virtual enterprise. The model is presented in the form of a table.

One dimension of the table breaks down the processes of instigating, devising, forming, operating and dissolving a VE. Each step requires decisions, the primary defining rule for inclusion. A best agile practices study conducted by the group validated the general approach and refined the breakdowns.

The other dimension of the table concerns decomposition of the VE's infrastructure. Since the creation of a VE is the creation of infrastructure of different kinds,

this breakdown is fundamental. Some of the infrastructure categories are better understood or relevant to the types of situations of interest, so are better articulated than others. Infrastructures that are most of interest for the Case Study are those dealing with business practices, contracts, workflow, and logistics.

The table defines cells that provide a granularity of processes that is helpful for agility planning. Certain cells could form the basis for an agility strategy, in which case others may be important in providing support. Still other cells may require attention in not negating the strategy. Examples that we have examined indicate that a robust agility strategy may address only a dozen or fewer cells in the model.

Employment of the agility metrics depends on the AVE Focus Group model for a clear definition of processes, a standard granularity of those processes, and a way of representing how each part contributes to the whole.

37.1.3 The Case Study Method

[How the case study is pursued.]

The Case Study is one task under a DoD research contract. Results from the Case Study(s) will be analyzed by the Automation and Robotics Research Institute (ARRI) and the AVE Focus Group. Perhaps elements will also be discussed on the email list. The results will be posted at the web site and included in the publicly available final report. Generally, the process of analysis and struggling with issues is an open one.

However, the project has a well tested, and long history of protecting the sources of information and insight. The presumption in working with the questionnaires and subsequent discussions is that company-specific information will be obscured to a sufficient level of comfort, to be defined by the source company.

We intend, in the full write-up, to wrap the Case Study in discussion of an example. Steps other than four will use a clearly fictitious context, based on a generic defense aerospace need. In order to ensure that none of the relevant insights are lost, we will seek the source company's certification that the results are correct in elements that matter, and that they reflect the state of the industry as best they know. Non-disclosure agreements can be executed.

Incidentally, we do intend to release the questionnaire generally, without fee, for companies to use. Feedback where volunteered from these sources will be incorporated. However, this is not an instrument where we seek large numbers of respondents in order to perform statistical analyses. Indeed, we expect to bypass the actual writing of individual responses where verbal dialog is more efficient.

Finally, helping the project with the questionnaire is presumed to be beneficial to a company in learning about our approach to engineering agile systems. The normal benefit that goes with self-examination in a new light will also result. But there is no consulting or advisory feedback planned. The ARRI can provide that at presumably modest cost, outside of the project. Or consultants may use the tools also.

37.2 Questions (with Explanation)

[The questions, with extended explanation.]

37.2.1 Structure

[How the questions are structured.]

There are two primary groups of questions. The second group contains the $64 questions, with the first providing context. In each case, the normal form is:

"do you have a such-and-such",

followed by questions that presumed that you did. We expect that in many, probably most, cases you will *not* have a such-and-such. But please go on to answer the questions *as if you did have a such-and-such*, presuming that you can reasonably imagine having one.

The questions are written as if they were to be repeated for each of the twenty example cells of the model. However, your responses are likely to be identical for many of these.

We expect that the easiest way to respond to all questions will be verbal rather than written. So if you are encountering this questionnaire cold, so to speak, and you want such an interaction, please contact Ted Goranson (757/426-6704, tedg@infi.net) or Jamie Rogers (817/272-2495, jrogers@arri.uta.edu) to arrange for that dialog.

37.2.2 Group 1: Existence of Controlled Processes

[Of the twenty cells, do you have some to which you currently assign resources?]

Please review the AVE Focus Group Model. We've selected twenty example cells which, based on initial interviews, appear to be cogent to conventional prime-supplier relationships in the defense aerospace sector. Use these or a self-selected set that is more cogent to your business.

We expect that there will be many cells for which there is no *real* process, even in agile enterprises. A *real* process is one to which costs are allocated. What cells do you have real processes to support?

Probably there are a number of cells for which you do not have processes, but for which you can easily imagine a process set up and supported by your company and suppliers. What cells fall into this category?

The remaining cells are ones which your enterprise would not naturally support as it is. Which of these fall into the following categories:

- It's too hard; we know enough about how to do it to know it's unrealistically difficult;
- It's too expensive; we know how to do it, but it just doesn't seem worth it;
- It's too alien; we haven't an idea what you're talking about;
- It's contrary to our corporate culture or strategy; getting into this process contravenes or negates some other cell or philosophy on which my company

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depends;

- There's some other barrier (for example a regulation).

Next, presume that you have one or more candidate processes in mind for each of the cells. If you were evaluating an existing supply chain's agility, these would have to be existing processes. If you were evaluating various options for a future, engineered supply chain, they could be notions, but notions of realistic processes.

However, we'd like these processes to be engineered processes. In addition to consuming costs, a requirement from above, they should each *require management attention*, they would be controlled processes.

For the processes from above, are they planned, engineered, and controlled to achieve best effect, regardless of agility? Or are they largely default processes, evolving of themselves. If they re not engineered, can you imagine them to be so?

37.2.3 Group 2: Representation of Processes

[Section asks how the processes are currently represented.]

37.2.3.1 Review

Let's review. What you should have now is:

- A threat or opportunity. The suggested opportunity for the missile prime is how to fill the customers' need for missile variants while only generally knowing the nature of changes in missions and technology.
- One or more themes for your strategy; you may call these high level or general strategies. Such strategies are based on your strengths, on business strengths and goals, and on specific peculiarities of the situation.
- A breakdown of each strategy into a small collection of relevant cells of the AVE Focus Group Model.
- Possibly several candidate processes for some of the cells.

There are many ways to use the metrics. In this example, we assume that you will be using the metrics to evaluate both:

- Which processes being considered for a cell are the most agile; and,
- Which small combination of populated cells provide the most effective agility strategy.

37.2.3.2 The Leap

The main task in using the metrics is to make a transition in how these processes are represented. We need to get from however they are currently represented and understood, to a specific representation we need to evaluate the metric. The good news is that by working with the AVE Reference Model, as you have to identify processes and cells, three hard issues have been addressed.

- Processes with different underlying mechanics have been separated; the under-

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lying mechanics of what goes on in, say the contract universe, is different than those in the physical world. Breaking things down by our infrastructure columns takes care of that.

- Each process must support a decision. We are engineering the control structure of creating and operating agile enterprises. Processes only have meaning where they affect this control. Working with the Model's rows takes care of that.
- We need to have a standard level of granularity for each of the processes we start with. The cells provide that armature.

So, although the Model may have broken things down differently than you might otherwise do in your organization, it's been for a purpose. Please consider the cost and difficulty of breaking the processes down in this way, the Model's way, as you answer the questions.

We need to go from however you understand your process to an act-based understanding of a few elements of that process.

37.2.3.3 General Needs

Information Theory has a well developed formal mathematics of information-based processes. In particular, there are notions of complexity which can be derived and analyzed. Some of these complexity metrics correlate well to a process's ability to adapt to changes in adjacent processes. Our metrics leverage these results.

We need to translate some elements of the business processes into these information-theoretic types of processes. The good news is:

- We need only a small portion of the information captured in a typical business modeling or engineering exercise.
- This is generally the easiest information to obtain if the process is understood. It focuses more on the structure of the actions involved and less on the details, like what triggers the action and how it fits in sequence. Also, we don't care how long an action takes.

The bad news is that the processes in this case involve suppliers. Suppliers are used to being asked about quantities, times, cost and quality. In rare instances, they might be asked about the effectiveness of their process. But they are not used to being asked questions about the *structure* of their internal processes. A significant percentage of the cost of the metrics may revolve around just getting the suppliers to understand the question.

Each process from the Model's cells gets decomposed into its set of *communicative acts*. Much information will be discarded if this information is being taken from a business model (such as those supported by Intelligent Systems Technology Inc. or Knowledge Based Systems Inc. or Intelligent Systems Technology Inc.

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Generally what we need is who the actors are, what they *say*. to whom, and in response to what other acts. It's an intuitive representation.

37.2.3.4 Specific Needs

The Speech Act representation breaks a process down into:

- *Actors and acts*. The acts are simple communicative acts which have a well-known breakdown. Non-speech acts are *ship* and *pay*. Speech acts are of two types, *solicit: request* and *question* and the second type, *assert: inform, commit*, and *refuse*.
- Characteristics of the acts. There are four:
    - *Responds to*: every act is prompted by an act which precedes it. The presumption is that all acts except the first are contained in the process.
    - *Replies to:* to which act the response is addressed. Can be different than the *trigger* act.
    - *Resolution* is the state of closing an conversation internal to the process. Some acts are resolved before the process is completed.
    - *Completion* is the state where all conversations are resolved and the process terminates.

This sounds more complicated than it is. In practice, the process is simply who says what in response to what and is the type of modeling managers like to do with post-it notes. For the metrics, it's not important to know what type of act is what, nor what any of the characteristics are. But they are useful guidelines in keeping the breakdown consistent.

We use a table to capture this information, but there are also graphical and algebraic formats. Computing the metrics from this table is automatic. We have a simple application which can do it, but simple arithmetic is all that is involved.

Doing such a breakdown is easy because it's intuitive. Typical processes concern only a dozen or so acts. It's complicated a little because the breakdown introduces some context, this from the original agility *threat*. But what makes it possibly expensive is that the interesting processes we are monitoring involve actors distributed among suppliers. Understanding processes in suppliers at this level may be difficult.

This sketch simply outlines what's needed; more information, of course, can be provided.

37.2.3.5 Actual Questions

For each process that you identified, please tell us on a scale of 1 to 5 how difficult (meaning costly) it will be to get the information we noted. Five is very costly. Remember that you need to include suppliers in virtually all of these processes. (Please give us a rough order of magnitude how many dollars per process you have in mind for the 1 through 5 assignations.)

Please let us know for each process whether the chief cost is in:

- Sufficiently educating all parties involved
- Understanding the agents (actors)

- Understanding what the agents do.

37.2.4 Extra Questions

The process of engineering agility follows the same steps of engineering other enterprise attributes, such as lean or quality. In all cases, the steps include explicitly representing your processes in some way. It's widely recognized that great value come from that step alone, even discounting further steps in the formula. Just exposing the workings of the enterprise to managers in a comprehensible way has significant power.

Quite apart from the whole process of engineering agility into your enterprise, do you think this perspective provides new insights into your processes? Would it make sense to you to deliberately use this type of system-level view of coupling (across the larger customer/supplier chain) to offset a reporting bias of other analytical views that might slight the *dynamic coupling* of processes?

37.3 Questions (No Explanation)

[The same questions in a terse format.]

Please review the example cells of the model (or cells which you select) and let us know which of these could anchor a workable agility strategy, given the scope of the agility problem.

- Please note these few cells and the candidate processes that might support them.
- If it is interesting, tell us why the others aren't viable.

For each process that you identified, please tell us on a scale of 1 to 5 how difficult (meaning costly) it will be to get the information we noted.

- If it is interesting, give us an indication of the major difficulties which make it expensive.
- Quite apart from the whole process of engineering agility into your enterprise, do you think this perspective can provide new insights into your processes?

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38 Case Study Results

[The results: expectations of effectiveness were supported, modeling costs are about $1M. The reasons are given.]

The following was learned:

- Although the benefits of agility and effectiveness of metrics are assumed to be reasonably well known at this point, devising an agility strategy is non-trivial:
  - Agility usually costs money which could be put to other strategic investments; relationships of agility to other tactics needs to be evaluated.
  - Agility in some dimensions counters agility in others, so the general shape and likelihood of the threat needs to be identified.
  - An agility strategy needs to work in conjunction with other elements of strategies within the virtual enterprise (market dominance versus immediate profitability, for instance.)
  - An agility strategy needs to leverage natural strengths in the current and possible partners' collective and individual core competencies and management philosophies.
  - There are few rules of thumb. General motivational frameworks by others working in agility are not very useful in detailing a strategy. It is difficult to separate different pure agility from more general, weaker definitions.
- Evaluating cells of the Reference Model is costly, but that cost is in line with other (equally costly) strategic evaluations:
  - Parties to be interviewed will be unfamiliar with the goals and purposes of the effort; processes to be surveyed will focus on traits that seem unfamiliar.
  - It will be easier, faster and cheaper to model the process elements of interest from *scratch* than to try to convert from existing models. In part, this is because the details of verifying correctness and completeness in the source model are difficult; the mechanics of translating among model formats, styles and methods are inadequate. In any case, the information desired will not exist either in computable models or in a readily available recorded form; the modeling process will involve the cost of raw information collection in essentially all cases.
  - Though one can narrow the reference model down to a few key cells, responsible strategic planning demands that many options per cell be examined.

The actual costs for our of modeling for our scenario are between $500,000 and $1 Mil-

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lion, with an hourly breakdown per cell as shown.

	A.e Depth of Customer Relations	B.b Risk/Reward Contracts	C.c Work Breakdown Structure	D.a Human Collaboration
1.3 Targeted Market	40	80	80	40
2.3 Partner Search	40	80	40	80
3.6 Risk/Reward Strategies	120	40	40	80
4.1 Performance Metrics	120	80	80	120
5.1 Identify Need for Change	120	120	120	80

Figure 38-1:Hourly Costs per Target Cell

- These costs are typical for similar strategic modeling tasks.
- We uncovered no hidden barriers, no *deal killers* in the basic approach.
- However, it is clear that this method, or any other strategic agility planning approach is in need of production-quality tools.
- In the military case, these should be integrated with the weapons planning and evaluation process known as COEA (*Cost and Operational Effectiveness Analysis*). Probably Virtual Manufacturing simulations will be involved.

38.1 Discussion

[The costs are in line with similar strategic modeling.]

It was a surprise that the modeling costs what it does. In retrospect we feel this is because the community has an idea of quality metrics which can be applied at a fine level of granularity without regard to strategic issues. Having a high level of quality is the strategic goal that is served. Agility metrics require a strategic vision and vice versa.

Lacking knowledge on modeling costs of similar strategic tasks, we turned to a major consulting firm (of several thousand employees). That firm performs many

strategic modeling tasks, *discoveries* they call them. The typical strategic discovery is $1 million, apart from analysis and the actual planning.

Clearly, there is a business case that can be made for an enterprise to do such an analysis. No small firm would do this on its own. It would have to be done from the point of view of the entire AVE. In the defense case (our scenario) agility benefits go to the DoD customer, so it is an apt function for them to sponsor.

39 Case Study and the ARRI Method

[How the metrics could be folded into the ARRI tools, as representative of general consultant's tools.]

The ARRI's enterprise engineering methodology team was a good match for us:

- We were both sponsored to work on agility and there is a specific clause in all agility contracts that encourages (actually requires) collaboration among agility projects
- They work in the aerospace domain, a key target for our sponsors. In fact, the Dallas/Fort Worth area has an unusual concentration of large and small aerospace-related manufacturers, many of which work with the ARRI.
- The group with which we allied has an enterprise engineering methodology which represents both the cutting edge of research and the moderating influence of practicality.
- With us, they share a respect for social and cultural issues in the enterprise.
- The ARRI hosted an NSF workshop on agility benchmarking early in the collective contracting cycle which raised many important issues.
- They have been active in the AVE Focus Group hosting a half-dozen meetings; in BAST, hosting that important workshop; and also in the ISIS-S/FIS workshop held in Alexandria VA.
- Even by DARPA/NSF standards, their work is first class, with an emphasis we share: methodological rigor.
- Their definition of agility as A3 agility, is the same that we use.
- Their location in the center of the country, near a major hub, is very convenient.

Moreover, they complement our mission. We intend to create tools that consultants (and other enterprise analysts) will use. They serve not only as a collaborator and auditor, but also as potential technology transfer partner, for their own use and demonstrating for others.

The ARRI method is typical of what many consulting firms do, except that they have a greater emphasize in rigorously understanding and refining the process. They have a way of decomposing the elements of an AVE, or even an ordinary company, into primary elements which reveal its behavior, then provide engineering principles, via *templates*, to accomplish formation or *re*formation to optimize certain goals.

Their decomposing of the enterprise is consonant with our reference model, though much more well developed because we need to support only agility, and they support manifold objectives. Their emphasis on templates as an engineering tool goes further than our metrics in that we measure only; they measure and suggest action. However, their decomposition lacks the internal dynamism required for A^3 agility, which we can add.

The next section outlines the salient features of their approach from our perspective (by no means being a fair *general* description.) The following section describes how our metrics can fit in as a special purpose tool. That description is

indicative of a general class of similar, though less formally defined approaches to strategic modeling.

39.1 ARRI's View Breakdown

[How their view breakdown fits with our infrastructure one.]

(The following information was adapted from ARRI material.)

ARRI considers the activity as the basic unit, using the same notion of activity we do. Concerning these activities, they are motivated to know:

- *What* are the activities that an enterprise performs;

  They seek to identify the essential processes (collections of directed activities) of the AVE.
- *How* should these activities be performed;

  They describe how the virtual enterprise and its members will perform these processes.
- How should the enterprise, the constellation of activities, be *constructed;*

  They include a methodology for the rapid reconfiguration to the AVE.

We address only the first two in the metrics phase, and the third in a future tool strategy.

In order to address these process-centered goals, they first break things down into five views:

- *Activity View*: defines the functions performed by the enterprise (*what* is done).
- *Process View*: defines the time sequenced set of processes (*how* it is done).
- *Organizational View*: defines how the enterprise organizes itself and the set of constraints and rules governing how it manages itself.
- *Business Rule View*: defines the entities managed by the enterprise and the rules governing their relationships (this view is equivalent to an information view).
- *Resource View*: details the resources and capabilities managed by the enterprise.

The perspective is *activity-based*, coming from an industrial engineering perspective. The bias is that you use all the views to understand what you are about, but your primary engineering focus, how you optimize what you do is focused on changing your activities. Naturally, you modify your business rules, organization and such when you explicitly consider them, but the engineering value is in how the *activities* can be optimized.

ARRI has detailed breakdowns of each of these views, based on the state of the art as enhanced by intensive real-world application. Each of the views has completely differing mechanics, and differing methods of modeling and analysis apply. A significant contribution to the state of business engineering is the result of these insights [ARRI91a [ARRI91b] [JMR95] [PJWL93].

The first of these five views is the world where the primary changes can take place, as we've noted. We'll come back to that in a moment. Consider the other four. These represent different views of the fabric of the enterprise; the actual physics in each view are different. This is the notion The AVE Focus Group used in defining infrastructures. You'll recall our infrastructures:

- *Social/Cultural*: dealing with hardwired psychological laws, community (ethnic, regional, national, etc.) cultures and corporate cultures
- *Legal/Explicit*, broken into
  - *Business Processes:* the explicit rules for how different elements in the enterprise interact. Who supervises and/or certifies which persons, activities or work products.
  - *Legal/Regulatory:* the codified definition consisting of the mostly external constraints governing key issues of how the organization functions.
  - *WorkFlow:* the logical sequence of what needs to be done by whom, using what resources and in what order
- *Physical*, broken into
  - *Logistics/Warehousing:* the physical sequence of what needs to move, when by whom and where from and to.
  - *Equipment:* the non-consumable physical resources used to conduct the work.
  - *Physics:* the immutable laws of physics

Note that there is an almost perfect mapping between our *infrastructures* and ARRI's *views*. This is no accident, since they were created with the same intent, to segregate behaviors which differ.

Our *Business Process infrastructure* is the same as ARRI's *Business Rules view*; the *Legal/Regulatory infrastructure* maps nicely to their *Organizational view*; and their *Resources view* has the same definition as what we call the *Equipment infrastructure*.

In other areas, there is no equivalent for our Physical infrastructure which is no problem. It's pretty useless from a normal decisionmaker's perspective and we only include it for completeness. ARRI handles information technology the same way we do, as something that permeates all views. We've created, for academic reasons the Information infrastructure which deals with issues of representation and modes of communication, but that's not of interest in engineering at the enterprise level which is why ARRI omits it. (It's an issue for government investment in next generation manufacturing research, which is why we include it.)

ARRI is more consistent than we are concerning social and cultural issues. Both of us believe it a paramount concern: ARRI deals with this by making a key issue in all views, as they do with information technology. We denote its importance by designating a separate infrastructure which we justify by positing that when a formal physics of this domain is found, it will be different in nature than the relatively hard behavior of the other infrastructures.

For now, it's a moot point which will be settled by the BAST activity. ARRI has major assets engaged in BAST, so we'll just have to see whose expectations were right.

39.2 Process View Mismatches

[The one apparent mismatch isn't.]

There's a mismatch of sorts with ARRI's *Process view*. We've broken that one view into two infrastructures, the *Workflow* infrastructure and the one for *Logistics and Warehousing*. We separate these two because the laws at work are different. The laws which govern material movement are exclusively physical; The Workflow adds non-physical criteria. Elsewhere we note that Workflow subsumes Logistics and Warehousing and that an adequate description of the former covers all the needs of the latter.

So why do we maintain the separation? Well, many of our infrastructures are subsumed by others in this fashion. And we maintain them all because different decision criteria can come into play. Physical constraints are so much more easily dealt with that we want to limit behavior to it whenever we can.

For instance, in scanning for partners, one might be able to eliminate or otherwise rank those which for physical reasons are handicapped. For instance, you are likely to eliminate a refinery from your petrochemical workflow if it is on the wrong side of the world, regardless of incremental novelty on process technology.

National boundaries are still defined physically. In the defense world, this issue of physical location matters for certain key components as well as a critical mass of the system.

Let's look more closely at ARRI's process view:

- *Generate, Accept, and Fill Order for Product*: Activities related to marketing the product, order entry, production planning, manufacturing, and invoicing customers for products.
- *Generate, Accept, and Fill Order for Service*: Activities including order entry, whatever service function was required, and invoicing the customer for the service.
- *Develop a New Product or Service*: Activities related to idea generation, market evaluation, major design development and manufacturing capability evaluation.
- *Identify and Fill Need for Non-Human Resources*: Depreciable: Activities which identify the need for such resources and acquire and manage the necessary resources.
- *Identify and Fill Need for Non-Human Resources*: Non-Depreciable: Activities which identify the need for such resources and acquire and manage the necessary resources.
- *Identify and Fill Need for Human Resources*: Activities which identify and fill the need for human resources. Includes hiring, compensation, and training functions.
- *Appraise, Improve, and Maintain Human Resources*: Includes goal setting, data

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compilation, data review and feedback to the employee. Also development of and transfer of information regarding salary, training, or other motivational programs.

- *Appraise, Improve, and Maintain Non-Human Resources*: Includes data collection a the operational level, data review and evaluation at tactical levels, and development of and transfer of information regarding resource maintenance.
- *Develop and Translate Strategic Plans to Tactical Plans*: This process covers the development of long-term plans and the translation of these plans to mid-term departmental goals, plans, and policies.
- *Translate Tactical Plans to Operational Plans*: This process covers the translation of mid-term plans and policies to short-term operational procedures.

These processes naturally fall into three categories:

- Those processes which use resources to produce enterprise results (The first three).
- Those processes which acquire and prepare resources (the next five).
- Those processes which transform external constraints into internal constraints (the final two).

This first category (the first three processes) include our logistics and warehousing constraints. There's much more to this breakdown, not discussed here including the development of *process templates*. Since ARRI has done such a careful job, it's quite easy to make the mappings from our two infrastructures into this one view.

In short, our infrastructures are the same as ARRI's views.

39.3 Activity Model

[How ARRI's activity definition compares to ours: well enough to believe translation tools can be forthcoming. How our scopes compare: as well as the different missions would allow. But there could be a problem.]

The ARRI follows a breakdown of Enterprise => Processes => Activities to reach their atomic level. We follow a breakdown of Enterprise => Processes => Process Instance (Cell of the Reference Model) => Communicative Act. Our notion of *process* is the same as theirs, but we cover a much grander scope, focused on the whole life of an AVE.

We deal with issues of whether the AVE should *exist*, should make something, what it might be, who might they make it with and how. ARRI deals only with the latter. We then go on to concern ourselves with de- or re-composing the enterprise.

On the other hand, we deal only with agility, which although new, novel and important, is only one of the many issues with which an enterprise would concern itself. The two approaches are complementary in this regard, which after all is the reason for the collaboration.

Back to the decomposition of Processes. The differences between us are purely a matter of the modeling methods we've chosen. ARRI is using the venerable IDEF0

methodology, and at the process level using IDEF3, a widely accepted choice. We've devised our own special purpose representation based on Dooley Graphs. We had to invent our own because no other would reveal the structure of the process which is indicative of adaptability.

We know we can map from their processes to ours and back. It's not clear that we can map from representations. We spent some time with KBSI who are refining an IDEF6. There is planned a more robust way of coordinating among IDEFs 0, 3 and 6 which together are expected to be able to support Dooley Graphs. But that's work left to be done.

Simply put, there is a workable mapping to and from our processes and ARRI's, with the promise of a more intimate representational mapping forthcoming.

Finally, there is a mismatch between the overall series of tasks that the ARRI addresses. The overall *Enterprise Transformation Methodology* has the following four steps:

- Develop Vision and Strategy
- Change Culture
- Integrate and Improve Enterprise
- Develop Technology Solutions

There may be an important philosophical difference here. In this sequence (which isn't strictly sequential), we can help with only the third step. ARRI follows the widespread convention that the enterprise should be tailored to meet the opportunity, that the opportunity is external in an important way from the competencies, culture and resources of the enterprise.

The AVE Focus Group took a decidedly different view, that agility depended on an introspective vision to understand what competencies, culture and resources *might* result from a manifold partnership and to extract on opportunity, perhaps even a completely unintuitive, nonapparent one.

It's hard to say whether this philosophical mismatch would act as a barrier to merging the two approaches. We did not have a chance in the case study to test the issue, but expect to have an opportunity in the near future.

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Part 4, Tool Strategy

40 A Tool Strategy

[What sorts of tools are expected to support the metrics.]

This section provides an executive overview of what types of tools are envisioned as a next step. One of these tools, Pomegranate, has been prototyped to the point that it can be useful now. Another, Turnip is just a demonstration of concept.

Four applications are reviewed. They work together to form the basis for a general framework, based on a deeply-ordered conceptual architecture that can tie together modeling and planning tools from others with emerging industry standard collaborative frameworks. The relationships to standards and frameworks is not discussed here, just the intrinsic features of the applications.

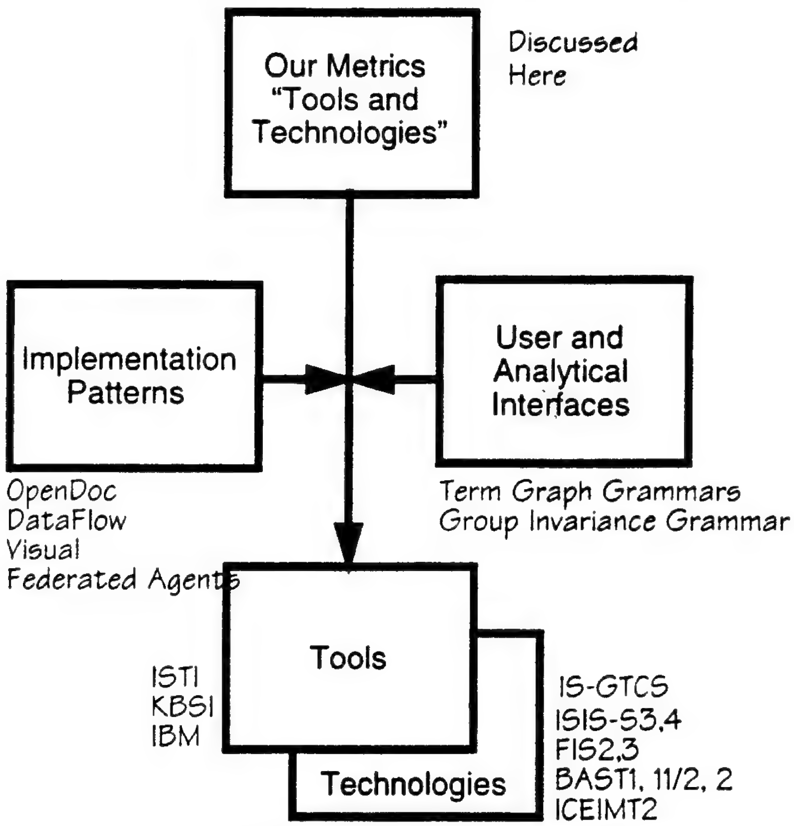

Figure 40-1:Novel Approaches at Each Stage

40.1 Brief Overview of Applications

[Outlines four tools which have been proposed.]

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There are four applications all together. They work together as show in the figure. We use their temporary code names.

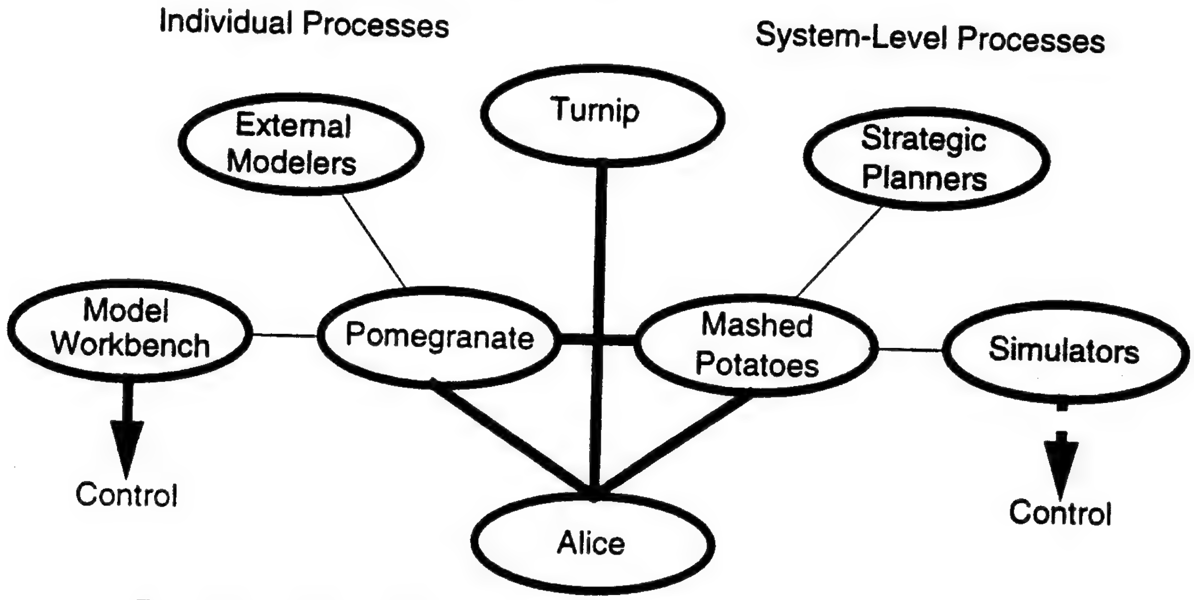

Figure 40-2:Tools Inter-relate with Each Other and Tools by Others

Pomegranate is a program that would be used by a decisionmaker or an associated modeler who is concerned with process models at the individual level. Understanding that process, and new analytical capabilities not found in current tools is the point of Pomegranate. Among these properties is the ability to evaluate that process's dynamic coupling with others, which, when given a context, reveals its agility as we've described. But the features can be evaluated for other characteristics as well (for instance, a new quantitative basis for quality that is not empirical). This tool would be best used in conjunction with a full-featured conventional modeling workbench as a plug-in.

Mashed Potatoes is its counterpart, evaluating all the processes in a Virtual Enterprise to determine its agility, or some other system-level metric which results from binding of infrastructure components. Mashed Potatoes' primary view is spreadsheet-like and is intended to interface with business planning tools (also as a plug-in or add-on).

Those two tools are intended to supplement decision-oriented analyses currently being performed. They are intended to integrate with current and planned tool suites in those domains. Since those suites are so radically varied--as well as the business models that they support--a high degree of flexibility is required.

The other two tools are made possible by the underlying framework which Mashed Potatoes and Pomegranate employ for internal representation. That internal representation is novel. It is designed to be *scalable* to complex situations, to capture *dynamic* features of individual processes, and to allow model *federation*. This last capability allows diverse models to provide input without first being changed.

For example, if you were a manager in a prime and wanted to evaluate a subcontractor today, you'd need their processes modeled according to your methodology and standards. Either you'd have go into that company and model their processes yourself, or you'd somehow force them to do it for you. Much of *prequalification* of suppliers is this harmonization of process methods. This is harmful to the enterprise because it typically spends more money on method harmonization to allow evaluation than on novel ways to integrate and leverage processes.

A common result is that businesses are forced to change their business philosophy to harmonize with the prime's; it makes the methodology normalization much easier. The bottom line is that: you end up with companies that operate like yours, even though competitive advantage often comes from companies which differ completely from you (which is often the primary reason for teaming), your potential partner pool is limited to firms which self-select to go to the trouble to do business with you.

We see this in the defense subcontractor base, as there has been a mass exodus, and since you need to use a general-purpose methodology, you are forcing your suppliers to abandon those quirky special-purpose methods that may have been adopted for their peculiar niche. The result is that all of the really capable people in your enterprise are using tools that are less powerful than they would otherwise choose.

Model federation allows the subcontractor to use whatever modeling methodologies they have chosen. You can incorporate that into your system model, having it appear in your system-level tools as if it were modeled in your lowest-common denominator method. You can engineer your whole system, perhaps changing the suppliers process (or suggesting changes). Those suggestions are seen by the sub in its native format. Their format is thus *federated* into the system.

How we accomplish model federation is not covered here [GORA92e]. The collection of methods we employ allows for tool integration as well and empowers some new abilities that managers may wish to use. Turnip is an example of one of these new tools. Mashed Potatoes would be used by a manager whose options are constrained by business options and guided by a specific business strategy. And its representations could be shared with tools that brainstorm new strategies or processes, or other types of tools that evaluate new configurations by novel simulations.

Turnip follows a different strategy. You might want to take everything that you know, information about all your possible suppliers, customers, competitors, and core competencies (which have been federated into the system) and noodle around with it, looking for insights hidden in the mush. This is much like what *business* analysts do with financial models. The difference is that what we have are essentially concepts. Internal to Mashed Potatoes, we turn those concepts, features within them, into numbers, so that the financial types can number-noodle.

But much of the real value of the concept is lost when transformed into numbers. How many horror stories have we all heard about bean counters making decisions based on numbers that are clearly wrong, even nonsensical? Turnip is one

of a class of applications that provides for conceptual noodling. In this case, the features of interest we chose were agility features, since that's clearly a high payoff area. But other features could be used as well.

A common application for Turnip might be to browse a large case base or experience pool, to look for hidden or underlying lessons learned, and whether and in what way they map to your current problem. The mechanism we use is conceptual clustering.

Alice is the tool for a whole new class of enterprise engineering geeks we'd like to see come into being. Turnip is for management analysts. Alice is for the programmer types who create tools like Turnip and who maintain the internal workings of the federation mechanism.

40.2 Implementation Philosophy

[Certain technical choices were made, and we explain why.]

As we mention below, these applications are intended to be useful in themselves when finished. But we'd like other people to adapt them, extend them, and integrate them in various ways. So we'll be giving away and licensing code. As a result, we have to be more careful about how we put these together than someone producing and selling tools in the conventional manner.

One guiding principle is to use a visual metaphor all the way down. Everything is based on graphic relationships. We divide the space into three layers and have a graphic paradigm for each of these. Because of fundamental differences among the layers, the graphic paradigm is not exactly the same as you go down, but some key relationships and principles do convey.

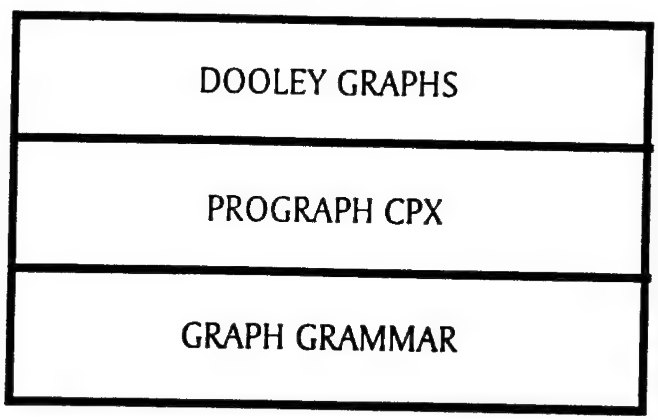

Figure 40-3:Three Layered Graphic Interface Paradigms

At the highest layer, we use Dooley Graphs. These are similar to state diagrams which are used to convey who said what to whom. We get a lot of leverage from these graphs as a token, because they can be abstracted from process interactions (which allows us access to model theory), from communications (which lets us leverage conventional information theory), and agents actions (which provides a basis for directed concepts and a host of associated useful disciplines). Dooley

Graphs do not capture all, or even most, of the semantic meaning in a collection of models. They do capture completely the syntactical structure of what is going on.

At the programming language level, we've chosen to use Prograph CPX [SCHM94] [SC95] [SHAF94], as opposed to a more common language like C or C++. We did this for a few reasons. It is an Object Oriented language, which helps with designing components that are modular and reusable by others in a sensible way. More importantly, it is the first thoroughly mature graphic programming environment. It's graphic all the way down; there's no text code involved. Graphic languages are much easier to convey to others, because the program structure and intent is so much clearer.

Also, of primary interest is that CPX uses a *dataflow paradigm*. We are dealing in an area where we've had to make basic decisions about how we deal with time, events, causality and sequence. The dataflow paradigm somewhat neutralizes these confusing issues. It doesn't matter what happens when, only what the pre- and post- conditions are. This also makes the code cleaner, easier to follow, and incidentally closer to the communication/agent state paradigm that we would like to leave to others (such as the Industrial Technology Institute) to leverage.

Finally, at the bottom level, we have the *concept engine*. This is no trivial piece of work. A functional programming approach (as opposed to procedural or object-oriented) is required, meaning at root a LISP. However, all of our work has been in instancing concepts in a graph (or lattice) grammar. In effect, this is also a graphic way of *programming*, or manipulating concepts. If someone wanted to tinker around at the concept level (and we trust there are those who do), this is the di-

mension in which they would work. An example of a typical graph from similar work in Germany [KAHL95].

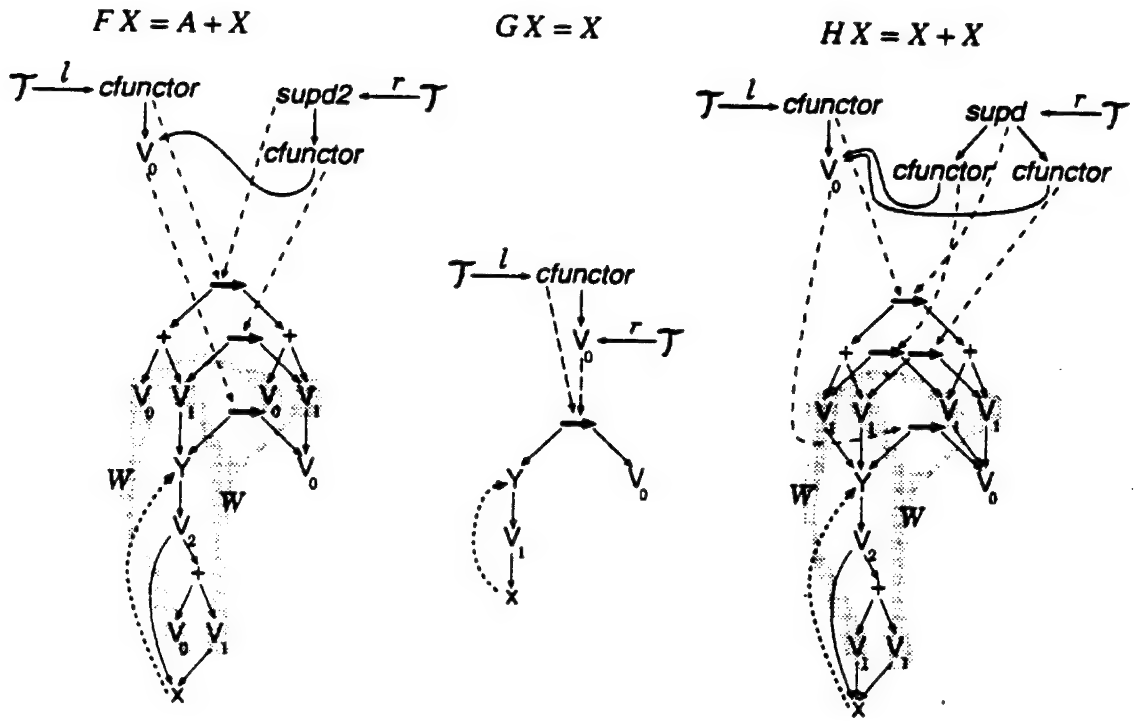

Figure 40-4:Kahl's Graphs of Term Grammars

We intend to leverage leitmotifs, conventions, styles, and a few operators across all three levels.

Pomegranate's class structure is given below, as is the Dooley Graph algorithm contained therein. Also, we have a more detailed discussion on the concepts of Turnip.

40.3 A Note About Names

[Why the codenames were chosen.]

You may be wondering why we chose the codenames we did. They are all silly. But in the spirit of full openness, here's the scoop.

Alice is the *Abstract Lattice Integrated Conceptual Environment* that we have been working on for some time. Historically, a test for such environments was whether concepts from literature could be captured and related. The book we tested was *Alice in Wonderland*. (We'll publish those results eventually.)

One would work with *Turnip*, the concept browsing tool to see what would *turn up*.

Alice and Turnip are *underground* apps; they work beneath the surface of conventional business operations. Mashed Potatoes serves up some of those under-

ground products in a satisfying way for ordinary people. In fact, Mashed Potatoes was inspired by comments made at the Agility conference in March 96 by a GM manager. He wanted no complications, just a *bubba list* of the top ten things he needed to do to be agile.

Fair enough. But agility has a lot of *it depends* qualifiers. Mashed Potatoes allows a normal financial/management bubba to scope the *it depends* factors, and see what the top however-many processes are, why, and how much they contribute to agility. The presentation is in familiar spreadsheet format.

Pomegranate is a wholly above-ground fruit. In this case, we decompose the fruit and examine each of the cells (that is, processes).

40.4 Pomegranate

[An application which has been prototyped. It calculates a Dooley Graph.]

This application likely would be the first one of the four encountered. We imagine it would be a plug-in or an internal service to a generic modeling workbench. A model has to be entered into the system somehow; perhaps it is entered by the host workbench, or federated in via Alice. Pomegranate helps the process decisionmaker evaluate some features of the model.

The features of these models which are of interest are basic properties concerning how they interact with each other: what their dynamic combinatorial properties are.

Pomegranate imports the process as is, or translates it into a communicative act. This format is tabular, capturing what happens, who causes it, who is affected, and implicitly what the pre- and postconditions are. The purpose of Pomegranate is to evaluate a given process or to explore variations on those processes (and even new processes). In support of the latter, Pomegranate has a speech act authoring interface.

One could tweak the models in either this form, or the originating form. Depending on how the model is connected to Pomegranate, the results of directed tweaking would be reflected. To tweak it in conversation mode, you would edit utterances (components of the conversation), using the utterance editor, which is opened when you double-click on an item in the list, or edit actors directly from the conversation editor.

When you've got something you'd like to evaluate, the Make Dooley button makes the Dooley graph. This is shown in the Dooley Editor, a mirror of which will also be shown in a blank upper right area of the Conversation Editor.

The status area at the top of the Dooley window has information about the metrics (the five basic features which describe dynamic coupling). By highlighting a node, as shown in the window, the status area shows information about the selected node. Experimenting with new designs in the graphic mode will also be supported.

The strongest part of Pomegranate is it's ability to suggest changes to a process by reference to stored (and evaluated) processes. A more powerful feature is a li-

brary of promising transforms that can be applied to a base process to explore ways of achieving desired characteristics.

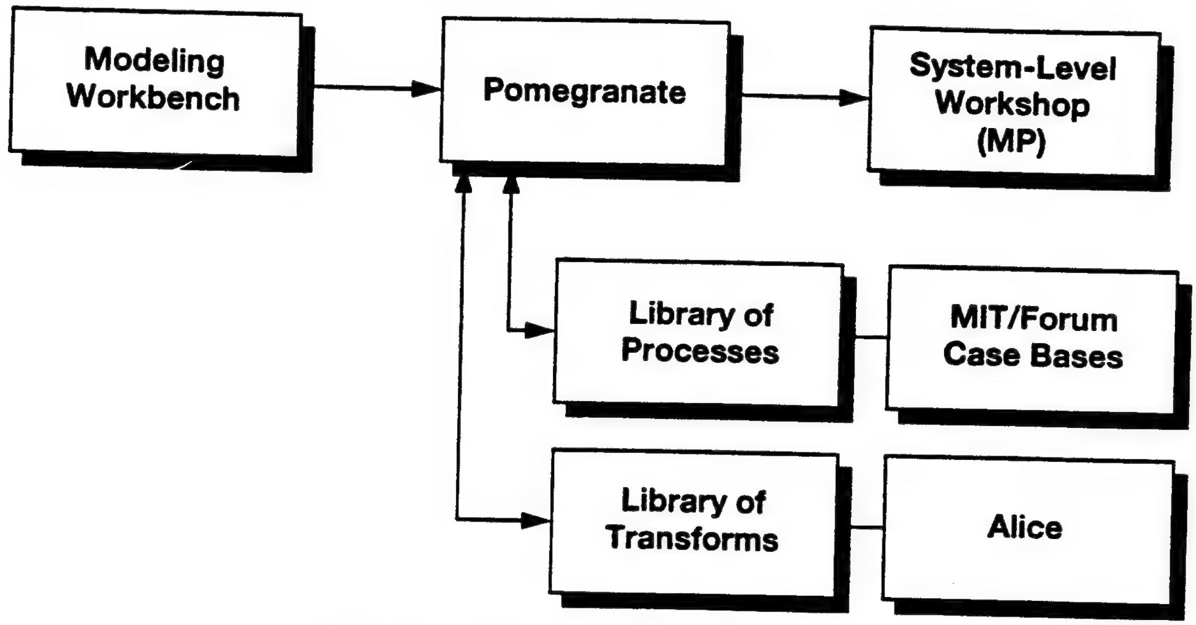

Figure 40-5:Library Connections

Details on Pomegranate, its screens and implementation structure, is below.

40.5 Mashed Potatoes

[An application to present numbers and patterns to a manager/analyst in spreadsheet-like form.]

Mashed Potatoes takes information on processes across an enterprise and evaluates its agility (or other dynamic properties). The Virtual Enterprise's agility is not a simple sum of agile processes. The weighting, dependencies and interconnections are complex, but there needs to be a simple way to play what-ifs. Mashed Potatoes provides this capability.

Ordinarily, one's first Mashed Potatoes screen would be the *Big Picture*. This is a familiar spreadsheet format. What's represented here is the standard model of agility processes developed over a period of a year and a half by the Agile Virtual

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Enterprise Focus Group. Down the side are the processes involved in the lifecycle of a Virtual Enterprise.

Big Picture

Total Agility = XX.XX	Business Processes	Contracts & Regulations	Work Flow	Logistics & Storage	Equipment	Basic Physics
Opportunity Strategy	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Exposure	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Targeted Market	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Search	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Partner Qualification	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Partner Performance History	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Partner Search	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Vision/Strategy Development	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Partner Criteria/Selection	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Enterprise Metrics	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Capitalization	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Product Liabilities	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Risk/Reward Strategy	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Operating Structure	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Dissolution Plan	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Performance Measures	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Customer Relations	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Operating Practice	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Need Identification	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Residual Liabilities	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Asset/Equity Dispersal	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX

Figure 40-6:The Big Picture Window

Part 4, Tool Strategy

Across the top are two large categories representing the two major infrastructures: Legal/Explicit and Physical, with each of them broken down into three divisions each. Clicking in many cells opens a definition or explanation.

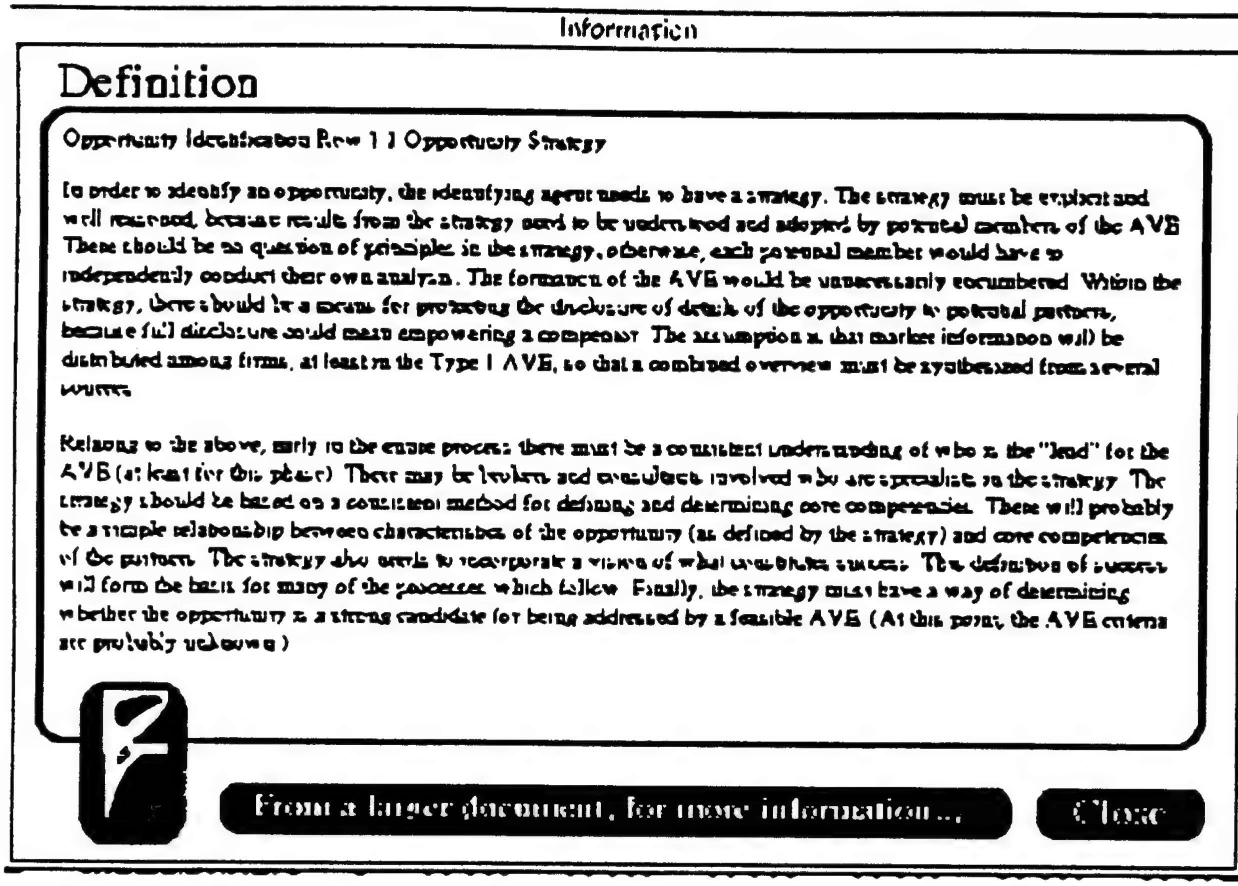

Figure 40-7:A Typical Definition Window

The *More* button opens the HTML version of the evolving Metrics project report. Clicking in the *Column* Headers expands that column into five subcolumns. Effectively the spreadsheet has 30 columns, but we collapse it this way to make it easier to see patterns. The complete infrastructure breakdown is in Part 1.

Part 4, Tool Strategy

As the Work and Technology Institute's Situation Theory work is productized, the Social/Cultural Infrastructure will be added. One of these *Column Expansions* is shown below.

Column Expansion

Column's Agility = XX.XX	Strategy Development	Risk/Reward Process	Engineering Quality	Work Scheduling	Customer Relations	Tool
Opportunity Strategy	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Exposure	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Targeted Market	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Search	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Partner Qualification	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Partner Performance History	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Partner Search	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Vision/Strategy Development	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Partner Criteria/Selection	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Enterprise Metrics	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Capitalization	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Product Liabilities	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Risk/Reward Strategy	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Operating Structure	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Dissolution Plan	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Performance Measures	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Customer Relations	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Operating Practice	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Need Identification	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Residual Liabilities	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX
Asset/Equity Dispersal	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX	XX.XX

Figure 40-8:The Column Expansion Window

Alternatively, one could click on a cell in *Big Picture*, and have the *Cell Expansion* screen opened. This is simply one row of the column expansion, but it contains additional descriptive text about the process.

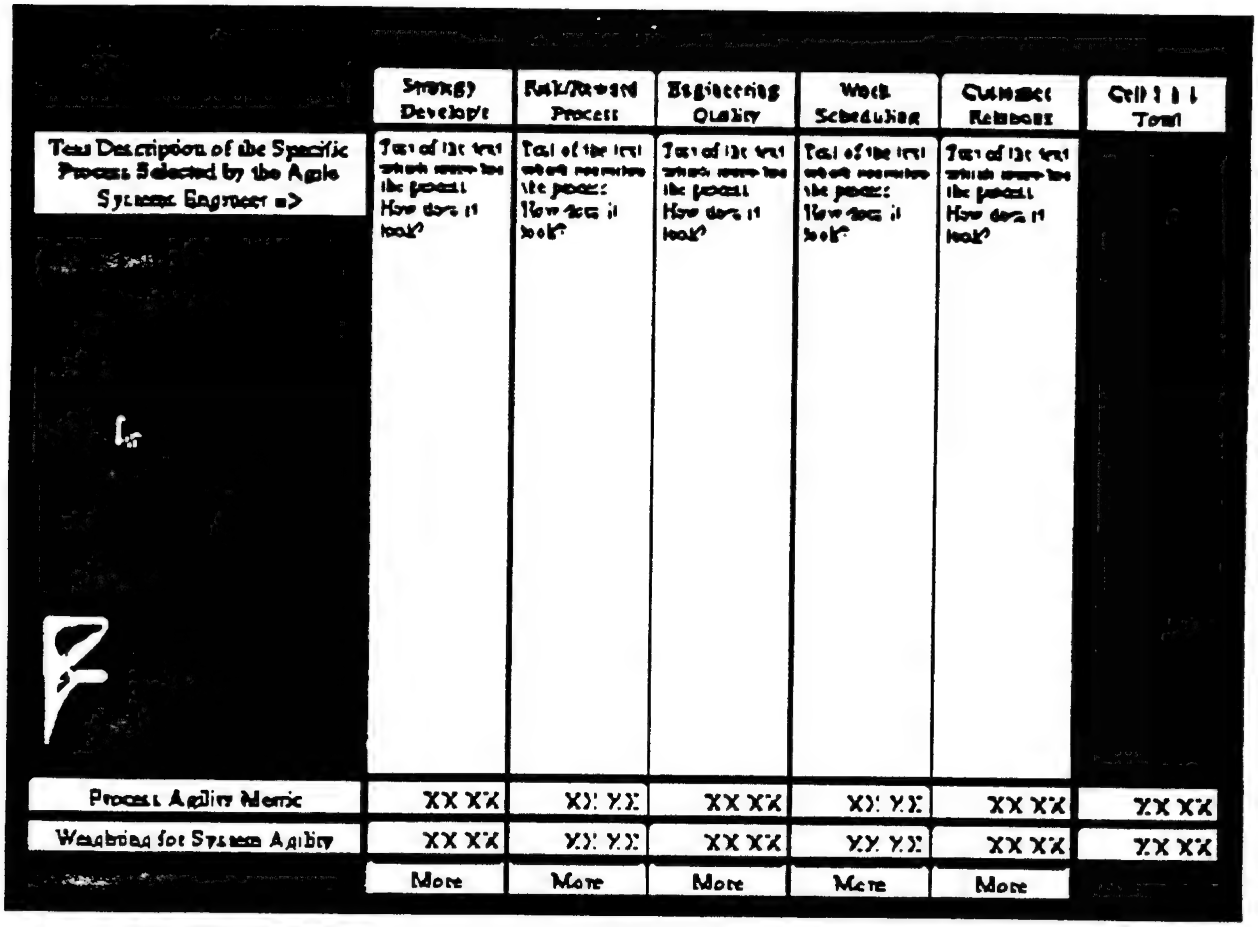

Figure 40-9:The Cell Expansion Window

All of these screens consist of numbers which give a composite number of the agility of the process or collection of processes to which the cell refers; the upper left of Big Picture gives the agility metric for the whole VE. Each of these presumes a specific context, as we've described elsewhere.

The cells of the *Column* or *Cell Expansion* represent small individual processes. Clicking on them opens the Process Selection screen. This complex screen is the core of the application. The currently selected process for that cell is shown: a text

description, the Dooley Graph, and the original form of the model (the cartoon here indicates in IDEF3).

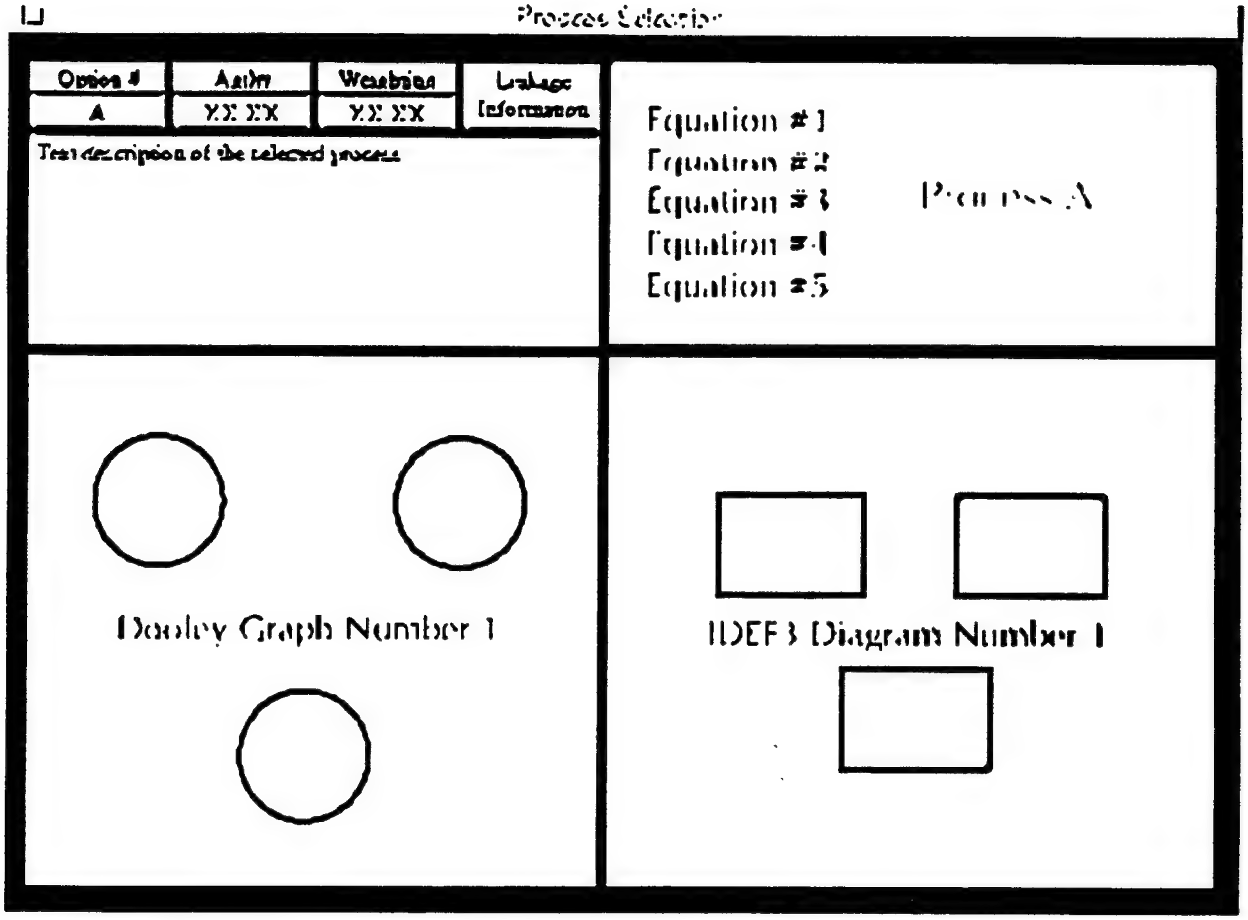

Figure 40-10:The Process Selection Window

Also shown is the calculation of the five agility features (which follows directly from the Dooley Graph) and the approximate combined, single number for the process.

Clicking on each of the process representations (it's number, name, text, Dooley or IDEF3 representation) opens a popup of stored alternatives of processes that could satisfy that cell. A manager could select an alternative process to see how its agility evaluates against the situation (which is provided by other tools, such as that being incubated at the Automation and Robotics Research Institute). Also, the manager can see how the selection affects the agility of the entire supply chain, both by seeing the weighting number and seeing how the combined number changes in *Big Picture*.

Again, we describe elsewhere that a process isn't intrinsically agile or not, it only becomes so when combined with others in an agility strategy. Also, it's importance depends on the situation in which the agility matters.

An additional capability to be added would extract the key processes (there will only be a few) and present them in a ranked list so that everyone in the supply chain knows what the key processes are to support the strategy and the scope.

Mashed Potatoes is a client. It gives and takes processes and metrics from two sources: processes from a library served by something like Pomegranate; and metrics to and from an organization's parametric planning software. (As one common format, Mashed Potatoes exchanges with Excel.) In this way, Mashed Potatoes forms a bridge between logical models used by process designers, and parametric models used by planners and managers.

40.6 Turnip

[An advanced what if tool, based on proprietary indexing science.]

Mashed Potatoes is a bridge between models and numbers, or more precisely between logical and parametric models. As described above, the initial use of Mashed Potatoes will be to feed parametric-based planning tools. The better of these will employ sophisticated methods such as multivariate analyses. The less sophisticated will simply use numerical methods.

But in both cases, the analyses will be on numbers. But our approach allows something more capable. On the way from a logical model, based on set theory, to numbers, we employ a category-theoretic abstraction of process features. It should be possible to perform system-wide operations on these concept features. Such analyses would be much more insightful since we are working with concepts directly rather than numbers which are a mere shadow of those concepts.

Part 4, Tool Strategy

Turnip is one of that new breed of analytical tools. How it fits with the other tools is shown.

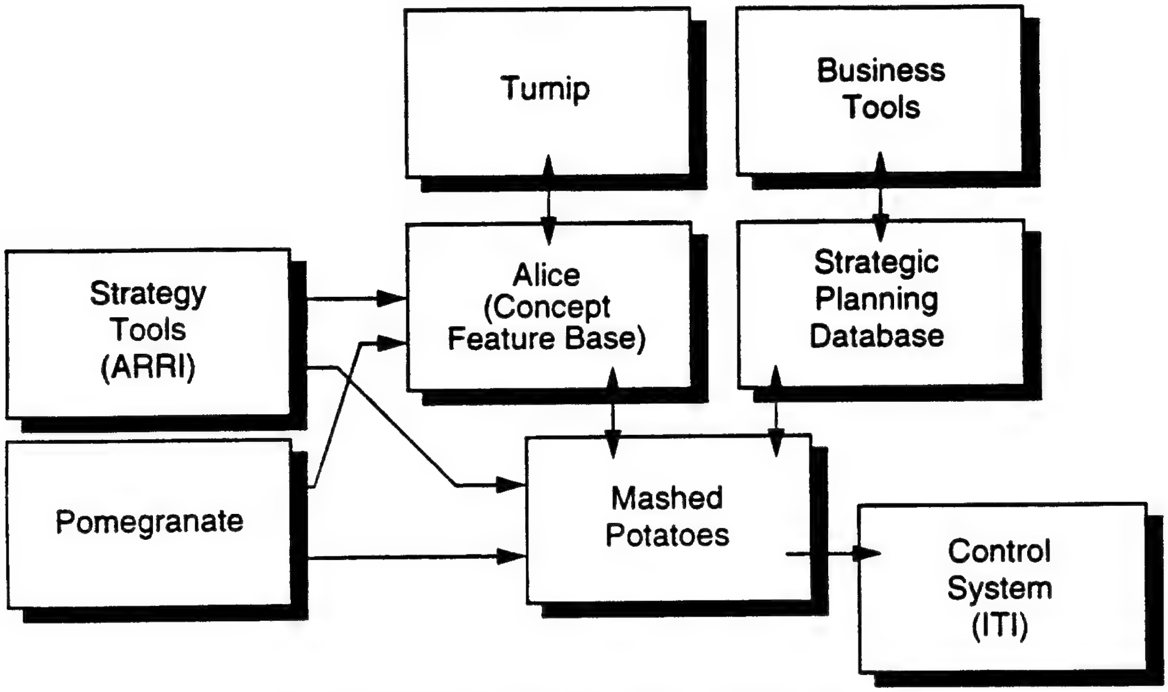

Figure 40-11:Turnip Supports Feature Analysis

The purpose of Turnip is to load concepts from all the process options (different processes, different suppliers), all the strategic options, and all the various agility scenarios. This could be a very large number (millions or hundreds of millions).

The idea behind Turnip is to form concept vectors, which is easy to do, almost automatic, with our graph representation. As with all our tools, we inherit techniques developed elsewhere. In this case, the techniques are from the Computational Fluid Dynamics area, with the cutting edge work being done by Sandia National Lab.

In Turnip, we define a five dimensional concept space, each dimension representing one of the features. In the figure, you can see that we either display or enter information into two dimensions at a time. The horizontal plane is the x-y plane

of those two dimensions. The z (vertical) dimension is the density of the concepts in the space.

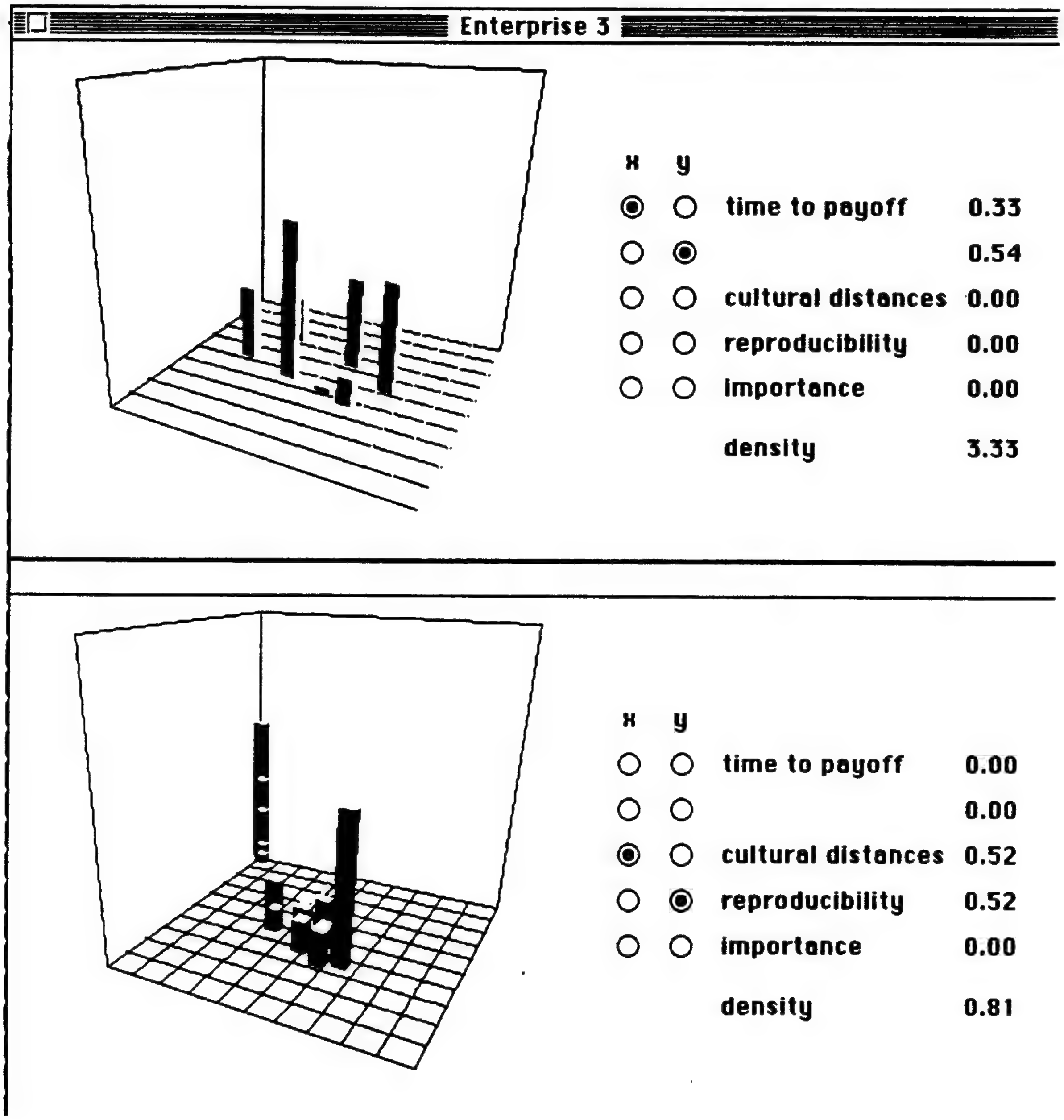

Figure 40-12:Two Views of Two Dimensional Vector Bundle Density in the Five Dimensional Turnip

8

In another version, we work in ten dimensions, adding dimensions for concept granularity. (Any number of new feature spaces can be employed, allowing evaluation of characteristics beyond agility.)

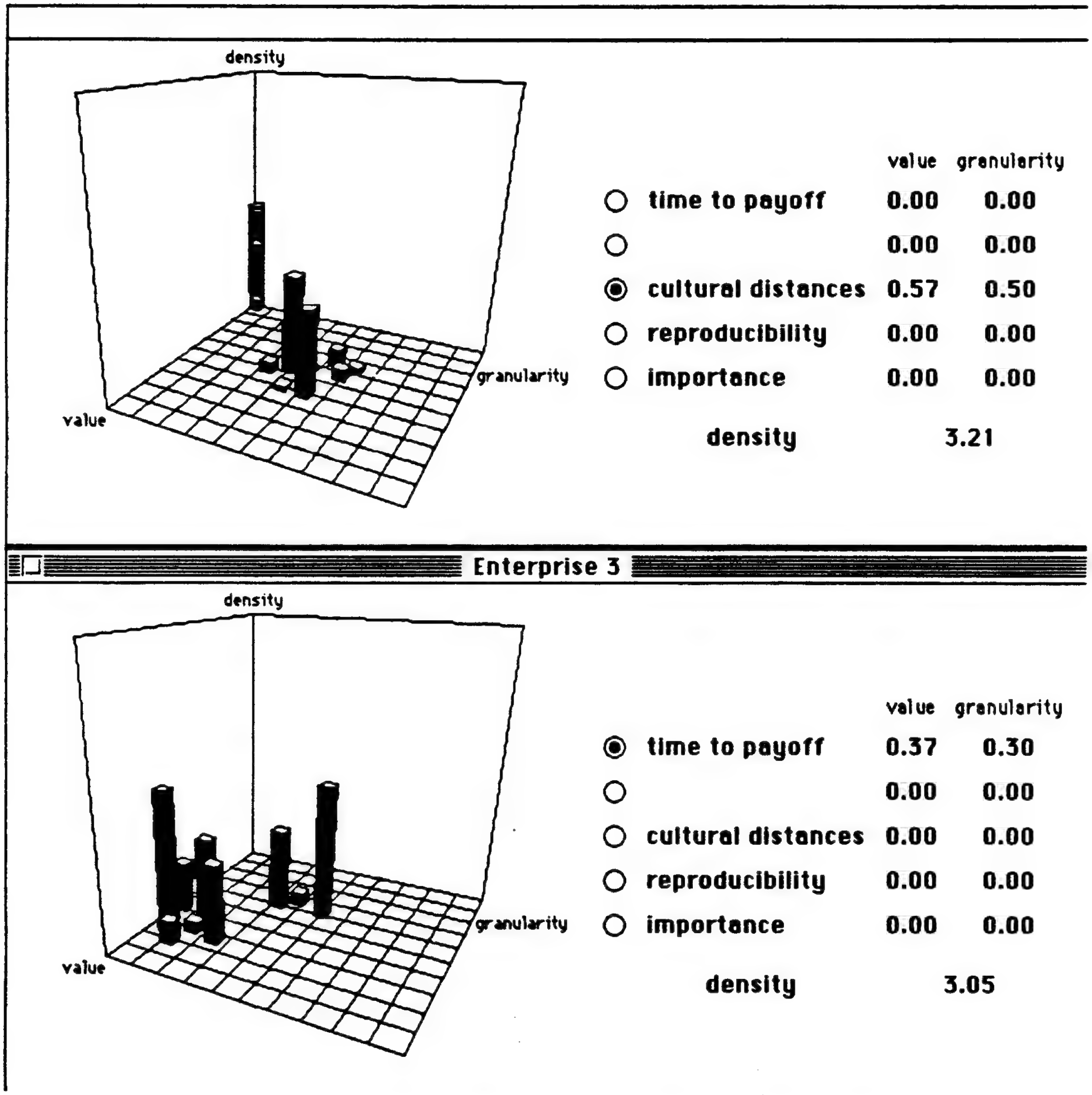

Figure 40-13:Two Views of the Ten Dimensional Turnip

What the analyst is looking for as the spaces are browsed is clustering of concepts: needs and solutions in the same space (strategy being either). The concepts in Turnip can be passively displayed, imported from a concept base like Alice

[GORA92i], or they can be entered directly in the windows shown, by drawing a concept flux density column.

As in Mashed Potatoes, system level evaluations of agility are computed. Each situation is considered a document and can be saved. Situations can be compared,

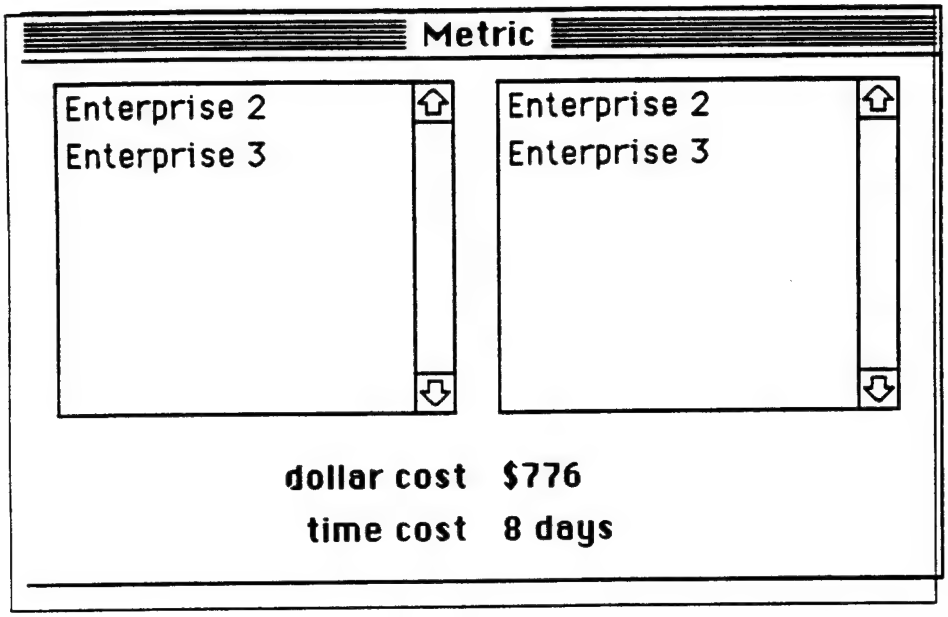

Figure 40-14:Any Number of Enterprises or Possible Enterprise Configurations can be Compared

Each situation is evaluated as to, in this version, the time and cost of accomplishing something, in this case, the combined cost of changing processes and designing/manufacturing with the new supply chain and new processes. Two situations can be compared from a scrolling list of many situations and the time/cost differences computed.

Mashed Potatoes is intended for existing decisionmakers; Turnip is designed as a tool for a new class of decisionmaker.

40.7 Future Work

[The intent to see these tools in widespread use, embedded in more comprehensive workbenches.]

We plan to take the components from the products and divide them into two classes. One class will comprise useful stuff in and of itself that we will make freeware, or essentially so. We're checking into *copyleft*, an open sharing system originated by the Free Software Foundation.

The other half will be licensed. In both cases, we plan to distribute some source code.

Meanwhile, you can download current versions of Turnip, Mashed Potatoes, and Pomegranate to play with. This is all pre-alpha code, developed for internal learn-

ing purposes. A patient explorer should be able to see what we're about. Use at your own risk! The web site, if you are reading a paper copy of this document is:

<http://www.agilityforum.org/Ex_Proj/MAVE/mave.html>

By the way, these only run on Macs. We're developing on Macs since only they have the 3D, other graphics, and the possibility of dynamic object support in the kernel. The tools themselves will be multiplatform of course.

Part 4, Tool Strategy

41 Pomegranate

[This is the design report, explaining the structure of the prototype.]

Information in this section was provided by Tangent Systems:

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41.1 Document Scope

[What the document is: a report on an emerging prototype.]

This document collects the requirements for the *Pomegranate* application, general goals for the application and major design/implementation decisions in the application. This document is not strictly a requirements document - it's more a *living* design document which tries to capture the major *drivers* for the application. The implementation information is included to give some context for discussing what the application does.

41.2 Purpose

[The prototype captures a conversation (process), produces a Dooley Graph, and prepares to report the metrics.]

The purpose of the application is to provide a means to capture a conversation as defined by its utterances and participants, evaluate the conversation using the *Dooley Graph* algorithm (described in the next section) and then to ultimately provide a mechanism to compare Dooley Graphs. The goal is to provide a framework to measure the *Agility* of a conversation. The application will initially support the use of Dooley Graphs as the mechanism for representing a conversation. A conversation can include the conversation that occurs between humans or organizations in an attempt to accomplish a goal. The Dooley Graph and metrics of a Dooley Graph may be used in a comparative sense to assess and predict the *Agility* of the interaction.

41.3 General Application Requirements:

[A list of the first stage requirements.]

- Provide a means to capture the utterances in a conversation.
- Provide a means to define the type of utterance.
- Provide a means to define the sender of an utterance.
- Provide a means to define the recipient(s) of an utterance.

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- Provide a means to define the participants involved in a conversation.
- Provide a means to calculate the Dooley Graph of a conversation.
- Provide a means to display the Dooley Graph of a conversation.
- Provide a means to import conversation models from external source files.
- Provide a means to apply various metrics to a Dooley Graph.
- Provide a means to compare a set of Dooley Graphs.
- Provide a means to print Dooley Graphs.
- Provide a means to Copy Dooley Graphs as pictures.
- Provide a means to print Conversation information in tabular form.
- Provide a means to inspect the metrics of a Dooley Graph.
- Provide on-line help.

41.4 Pomegranate Implementation

[We used Prograph/CPX.]

The prototype for the Pomegranate application is being built using Prograph/CPX. Prograph/CPX is a cross-platform visual data-flow object-oriented programming language and is produced by Pictorius, Inc. of Halifax, Canada. The application has won numerous productivity awards within the industry. The development environment includes a rich application framework, integrated application editor, interpreter and editor. CPX currently builds applications for Macintosh, Power Macintosh and Windows operating systems. The development environment supports the development of applications using state of the art object-oriented programming concepts. The basic application features rely on the CPX class framework - Application Building Classes.

41.5 Pomegranate Application

[Describes the workflow and support functions of the prototype.]

41.5.1 Work Flow Scenario

[The steps a user would go through.]

- User creates a new or opens existing Conversation Document. This results in a Conversation Document being created along with a Conversation Object and a Conversation Editor begin opened.
- User specifies the number (x) of actors involved in the Conversation. This results in *x* Actor objects being created and sent to the Conversation object.
- User adds utterances (here the user can add several utterances or single utterances and edit each individually prior to adding another). The editor provides a means to *add* new utterances to a conversation.
- User edits Utterances. The Conversation Editor window provides a list of utterances contained by the conversation. The editor also provides a means for the user to select a specific utterance to be edited. The result is the Utterance Editor

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is opened with the specific Utterance being the *customer* for its service.

- User asks the application to *calculate* the Dooley Graph. The Conversation Editor provides a means for the user to start the Dooley calculation process.
- The application creates a *smart* graphic in that the information driving the Dooley Graph (the nodes and arcs) can be directly inspected within the graphic object.

41.5.2 Support Functions

[Miscellaneous preferences.]

Preferences: The preferences in Pomegranate provide the capability to activate the metrics, enable drag and drop of files between projects and enable the database functions.

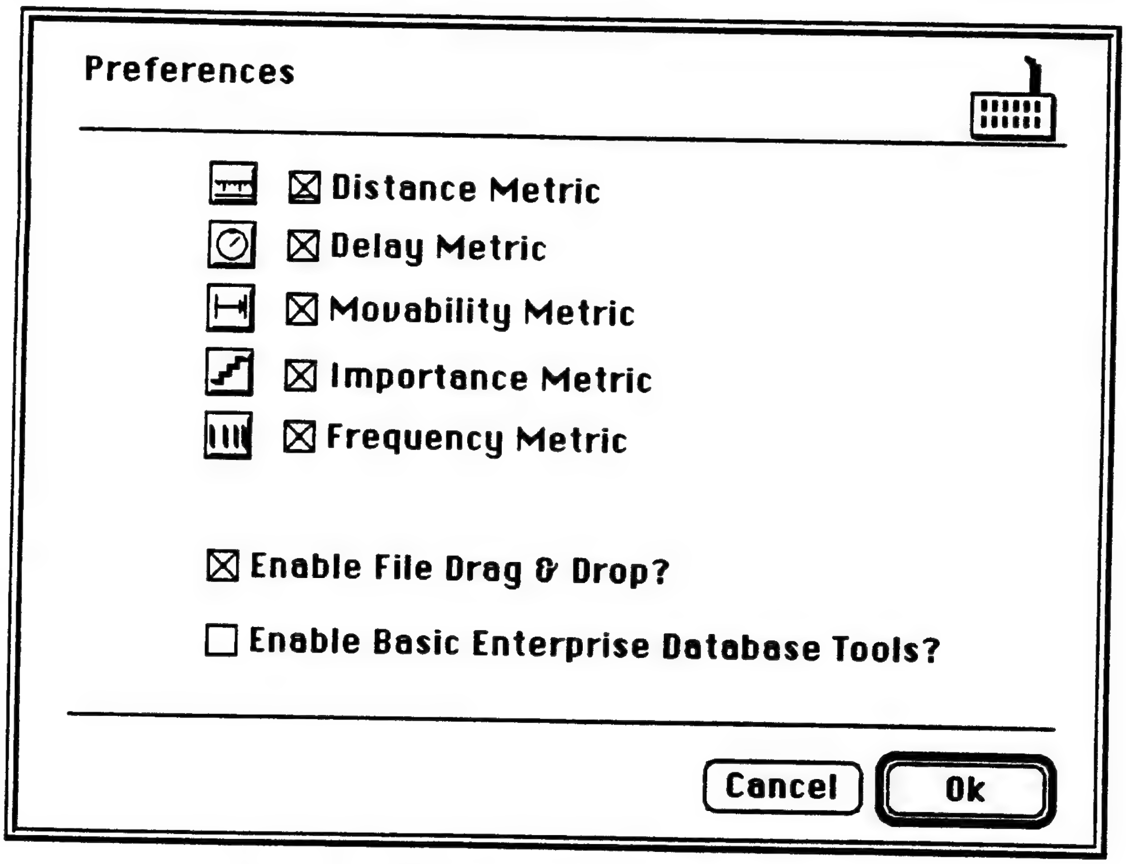

Figure 41-1:Pomegranate Preferences Window

41.6 Pomegranate Design

[Describes how the elements of the prototype appear and work.]

41.6.1 General Concepts

[Describes generally the inputs (utterances) and the output (a Dooley Graph).]

The *model* for the design is derived from[PARU96a] [PARU96b] [PARU96c]. The paper discusses in detail an approach to the definition of utterances and how the Dooley algorithm can be used to define the Dooley Graph for a conversation. The general idea is to provide a set of editors which capture the basic elements of a conversation. Those elements include:

- The set of participants. (Actors)
- The set of utterances. (Utterances)
- The relationships between sender and receiver(s) of each utterance. (Utterance Editor)
- Contain these elements inside of a conversation object. (Conversation)
- Define a class of objects which work with the Conversation to encapsulate the idea of a Dooley Graph.

Once the *conversation* is defined, the Dooley Graph is calculated using the Dooley algorithm or a function based on the Dooley algorithm. The graph is displayed in a window. The Dooley Graph window will also display a set of *metrics* which are to be determined - but will give a measure of the *Pomegranate* of the depicted conversation. These metrics will then provide a basis to compare to other conversations.

The use of the application centers around a handful of editors. Each editor is used to specify detailed information of a certain kind to help define a conversation or a set of conversations:

- *Project Window* - Manages a set of Conversation files.
- *Conversation Editor* - Add and delete utterances and actors in a conversation.
- *Utterance Editor* - Define specifics of an utterance.
- *Dooley Graph Window* - View the Dooley Graph for a conversation.

41.6.2 Project Window

[A collection of conversations (processes) is a project (enterprise).]

The project window manages a set of conversation files or documents. The window is designed so that related conversations can be grouped within a *project* in order to compare the *metrics* of the conversations. The window provides the ability to create new conversation files, add existing conversation files, remove conversation files, duplicate conversation that exist in project and to edit conversation

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files in the project. The Project Window also provides a way to sort the conversations using any of the available metrics.

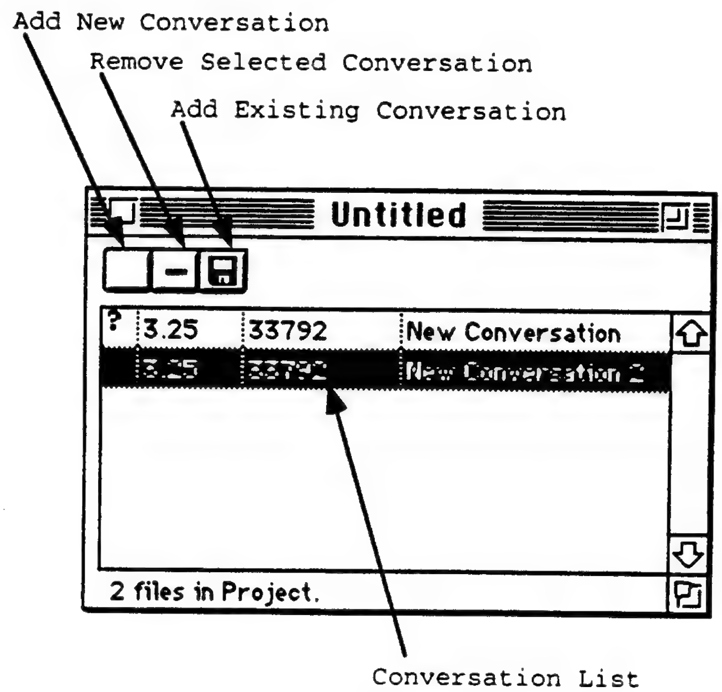

Figure 41-2:Project Manager Window

Summary:

- *Button* - Add New Conversation
- *Button* - Remove Selected Conversation
- *Button* - Add Existing Conversation
- *Popup Menu* - Sort Conversations according to selected metric.
- *Grid* - Display basic information about each Conversation in project. Provide access to selected Conversation file by double click action within the grid.

41.6.3 Conversation Editor

[A Collection of utterances (speech acts) is a conversation (process).]

The Conversation Editor provides the means to add and delete actors and utterances in a conversation. It also provides the function to calculate the *Dooley Graph for a conversation.*

Summary

- *Button* - Add New Actor
- *Button* - Remove Selected Actor
- *Select List* - Display Actors in Conversation
- *Button* - Add New Utterance

8

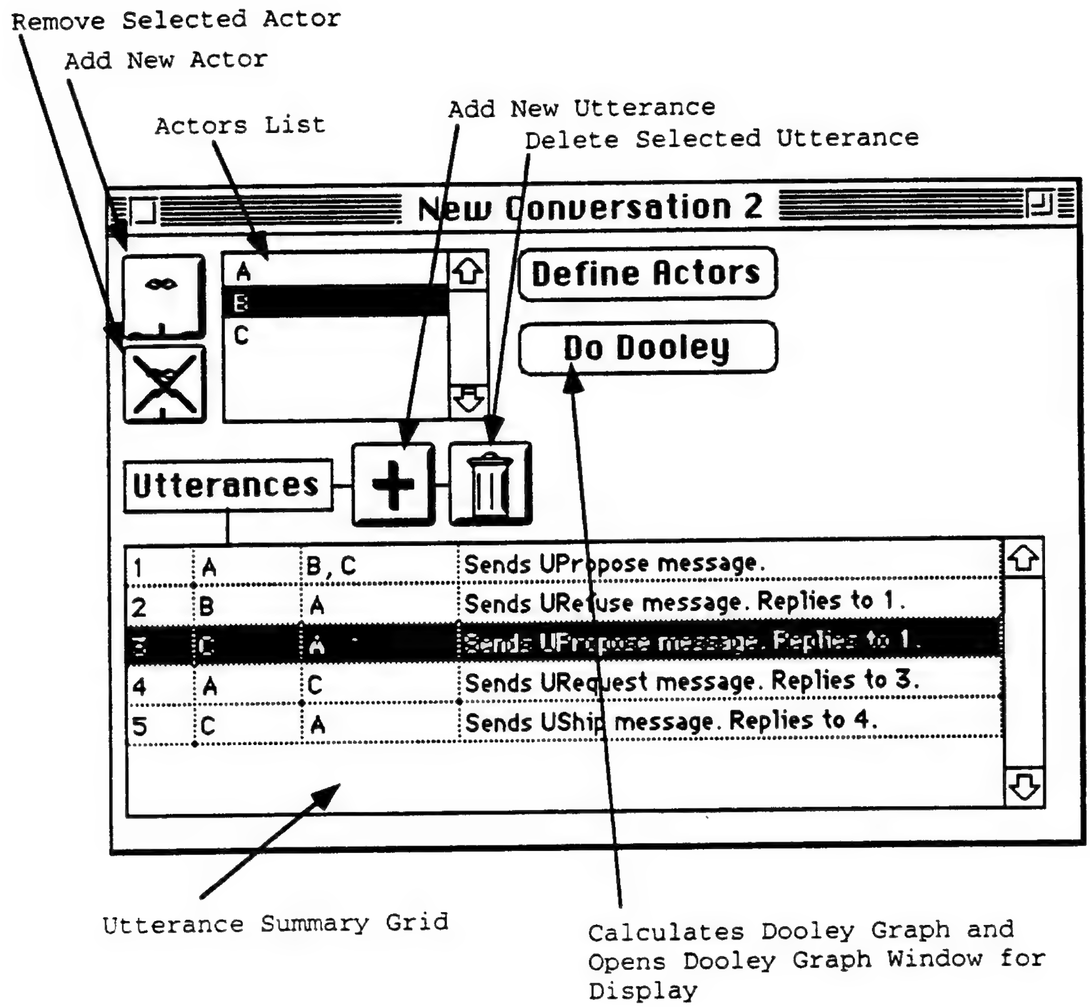

Figure 41-3:Conversation Editor

- *Button* - Delete Selected Utterance
- *Button* - Calculate Dooley Graph and Display Graph in a window.
- *Grid* - Display summary information about Utterances and provide access to edit selected utterance by double-click action in the grid.

41.6.4 Utterance Editor

[This editor specifies details of utterances.]

This editor allows for detailed specification of utterance. The sender of utterance can be specified along with the actors that receive the utterance. The utterance type is also specified. The window also provides functions to select other utterances in the conversation for editing.

As can be seen in the figure, the Utterance Editor Window provides several functions for specifying the nature of each utterance:

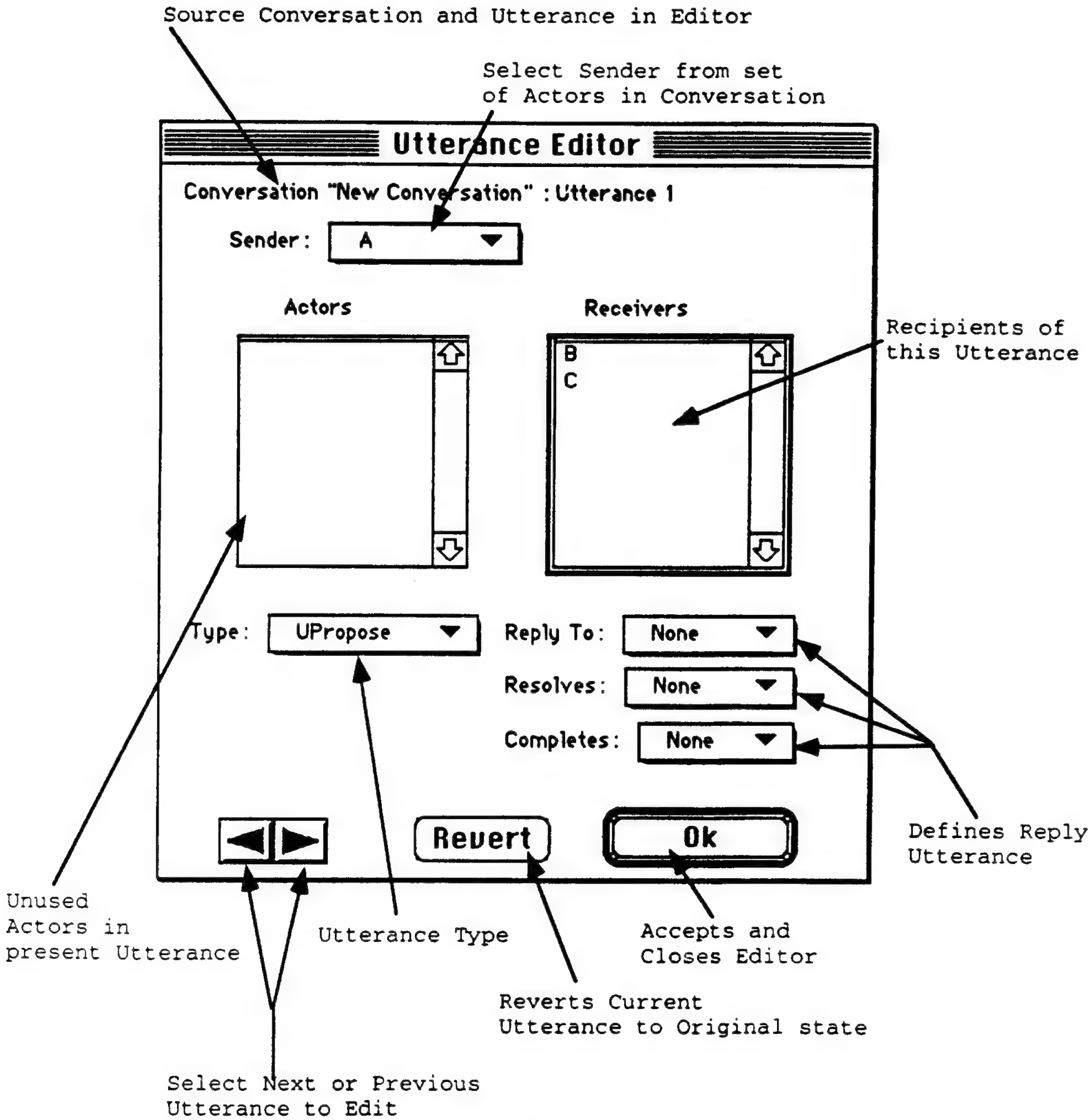

Figure 41-4:Utterance Editor Window

- The sender of the utterance is specified. Once this selection is made, the *sender* actor is removed from the selection list for specifying who is to receive the utterance.
- The recipients of the utterance are then specified by double-clicking selections in the left hand scrolling list in the window. Each selection will be then be added to the recipients list on the right-hand side of the window.
- The *type* of the utterance is then selected from the *Type* pop-up menu item.

• Then - and this is crucial for proper operation or calculation of the Dooley Graph - are the selections for *Reply To*, *Resolves* and *Completes*. Please refer to [PARU96a] for a discussion on what these attributes mean. Simply put, each of these selection defines which utterance the current utterance Completes, Resolves or is a Reply To.

41.6.5 Dooley Graph Window

[The Dooley Graph is displayed here.]

This window can only be opened from the Conversation Editor. It is opened when the *Do Dooley* button is pushed in the Conversation Editor and displays the Dooley Graph *graphically*. The window also provides buttons for display of each Dooley metric.

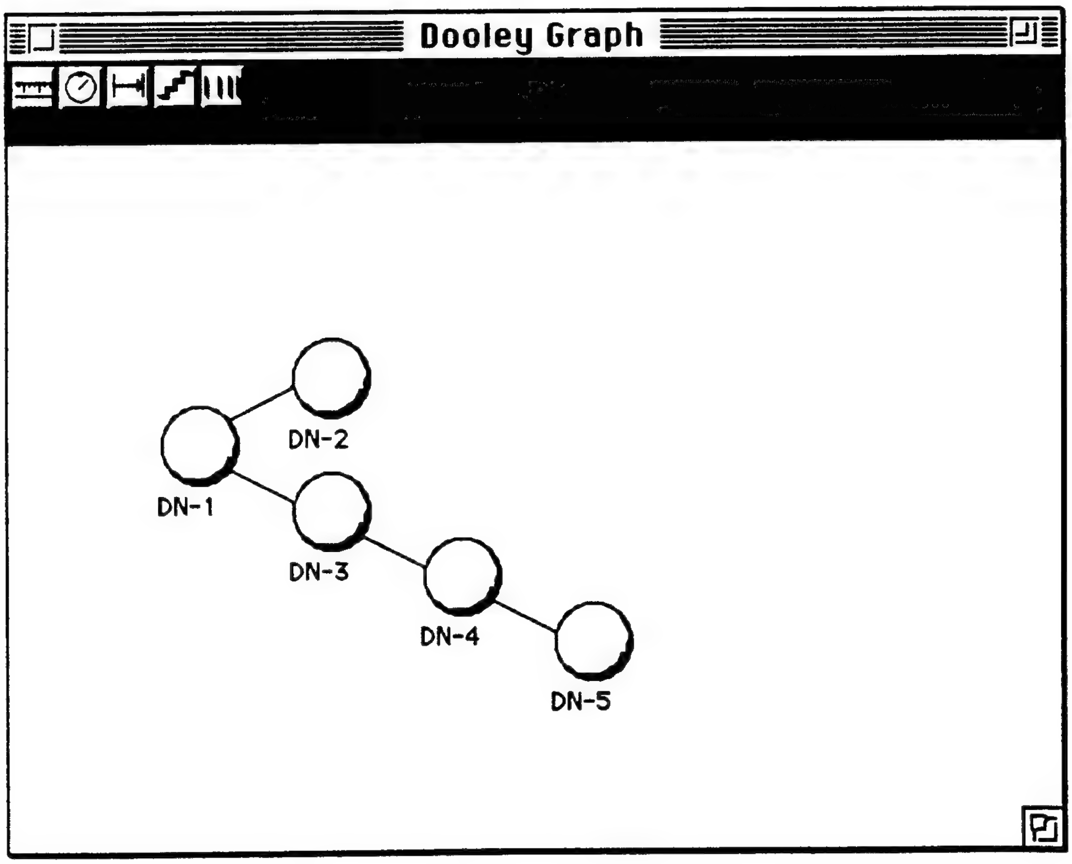

Figure 41-5:Dooley Graph Window

41.6.6 The Dooley Graph Engine

[How the Dooley Graph engine works (in words).]

This section will provide a short over view of the Dooley Graph Engine.

The basic framework for doing the Dooley Graph calculation is provided by the set of utterances defined in a Conversation. Given that the utterances have been properly defined - with regards to type and the various related utterances, the calculation of the Dooley Graph proceeds in a very straight-forward process.

The basic idea is for each utterance to create as set of Dooley Nodes and Dooley Arcs. Each utterance will keep its list of nodes and arcs. Some utterances may only create arcs while others may create both.

Each utterance *knows* who is sending it (the sender), the list of recipients, the utterance it completes (optional), resolves (optional), or is a response to (optional). The application is designed around this knowledge - the editors provide user tools for capturing this information and the utterances in turn use this information in calculating the Dooley Graph.

The Conversation Window has a method called */doDooley* that manages the process of calculating and then presenting a Dooley Graph. The method is divided into 2 major segments. The first part of the method calls another method */calcDooley*. This method creates an internal representation of the Dooley Graph. The rest of the method takes care of creating a visual representation of the Dooley Graph and opens a Dooley Graph Window to display it.

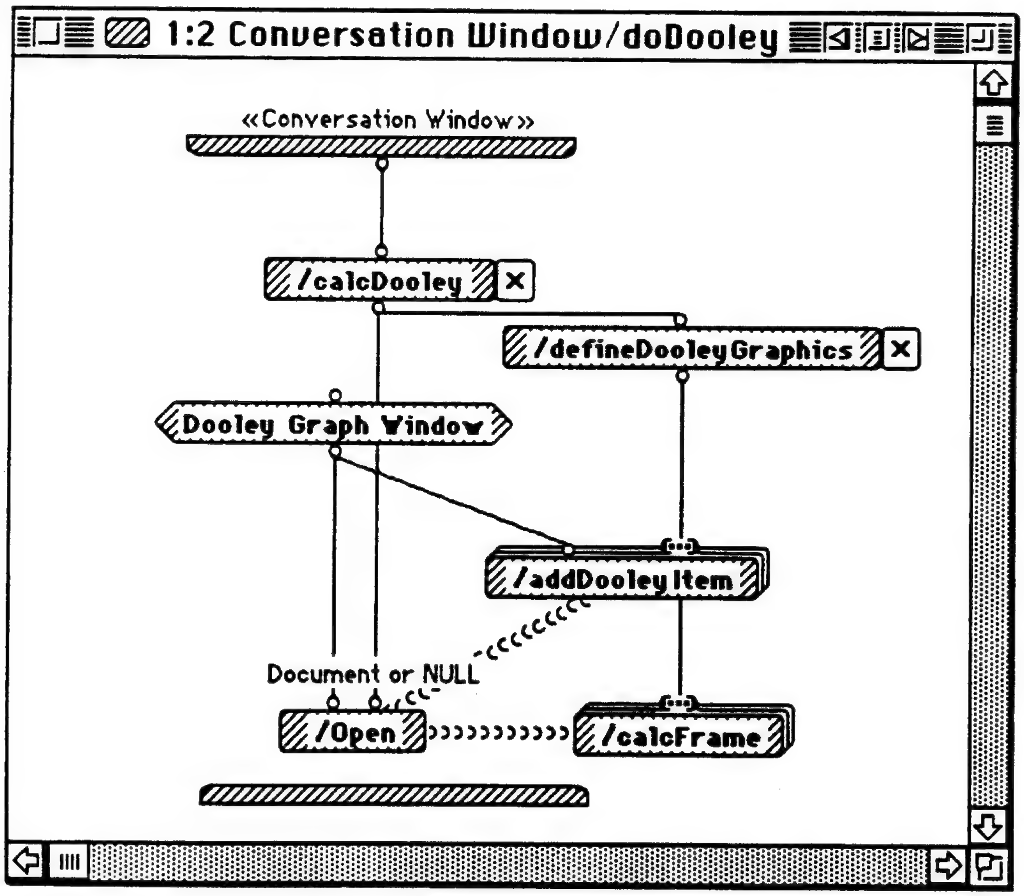

Figure 41-6:Conversation Editor/doDooley

The method */calcDooley* handles the calculation of the internal representation of the graph. It obtains the Conversation instance by the successive messages */Get Owner* and */Get Data*. The Conversation instance is then sent a message */doDooley*. After all, its the Conversation object that contains the utterances and actors

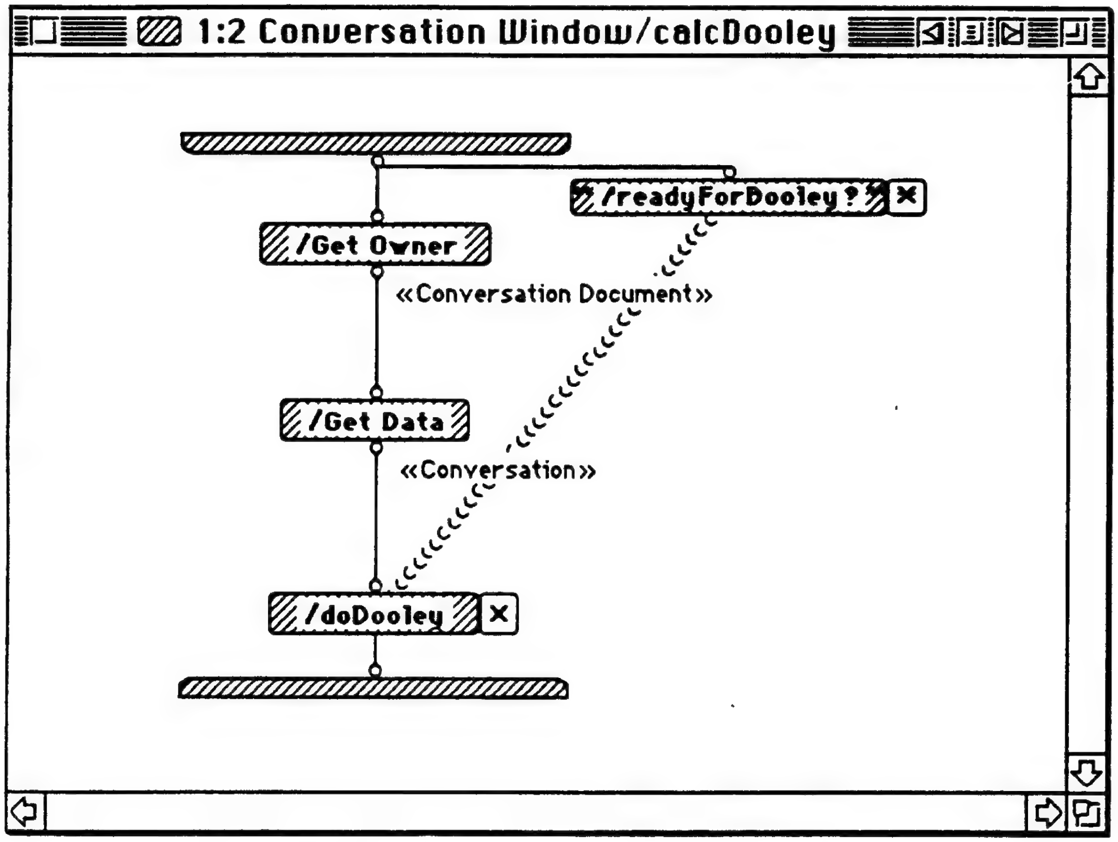

Figure 41-7:Method: Conversation Editor/calcDooley

Now the Conversation object will respond to the */doDooley* message by first figuring out the Dooley parts (Dooley Nodes and Dooley Arcs) in the local method *defineDooleyParts* If that method succeeds, it will then create a DooleyGraph

instance which will be used later in defining the visual representation of the nodes and arcs of the Dooley Graph.

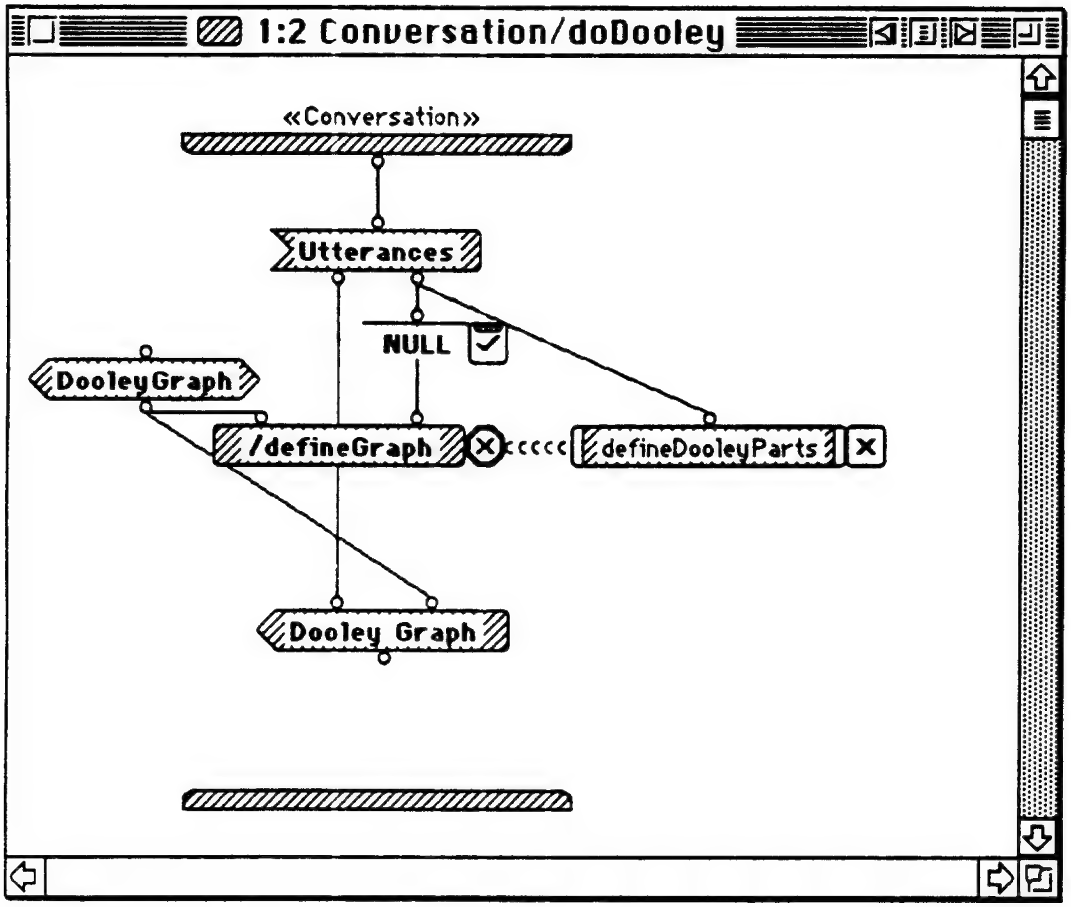

Figure 41-8:Method:Conversation/doDooley

The local method *defineDooleyParts* expects a list of utterances a for input. The first utterance is special and it is detached from the list and sent the message */do-*

ForcedDooley. The rest of the utterances are sent the message */beginDooley*. These messages/methods are described next.

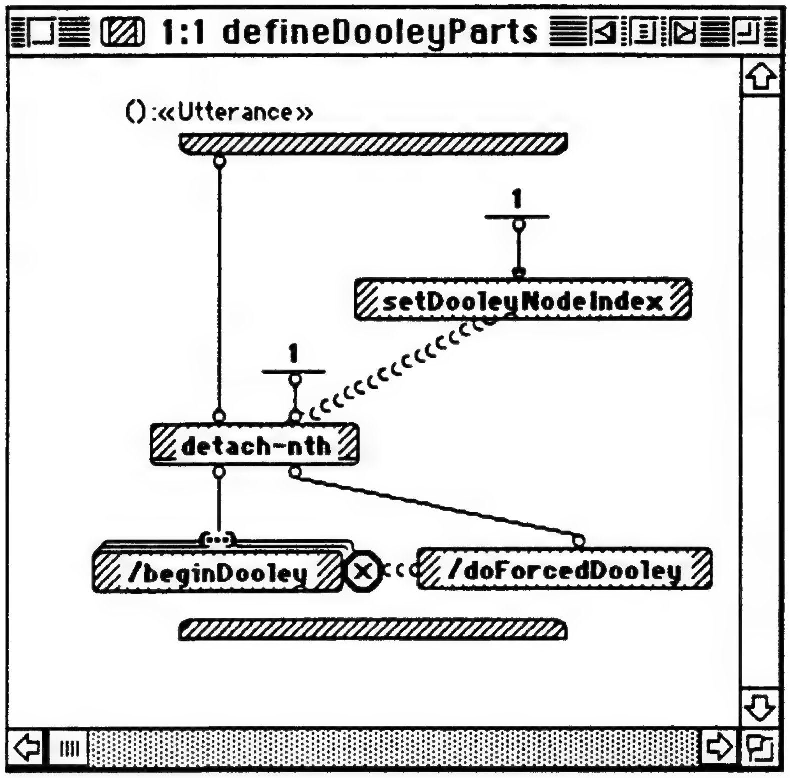

Figure 41-9:Local:Conversation-defineDooleyParts

The goal of method *Utterance/doForcedDooley* is to create a DooleyNode instance for the sender and for each receiver of the utterance. The method creates a local list composed of the sender (an *Actor* instance) and the list of receivers (a list of *Actors*). Then the method creates a list of DooleyArcs which pair up the *send-*

ing DooleyNode as the source node and the receiving nodes. In other words, a DooleyArc is created for each DooleyNode pair.

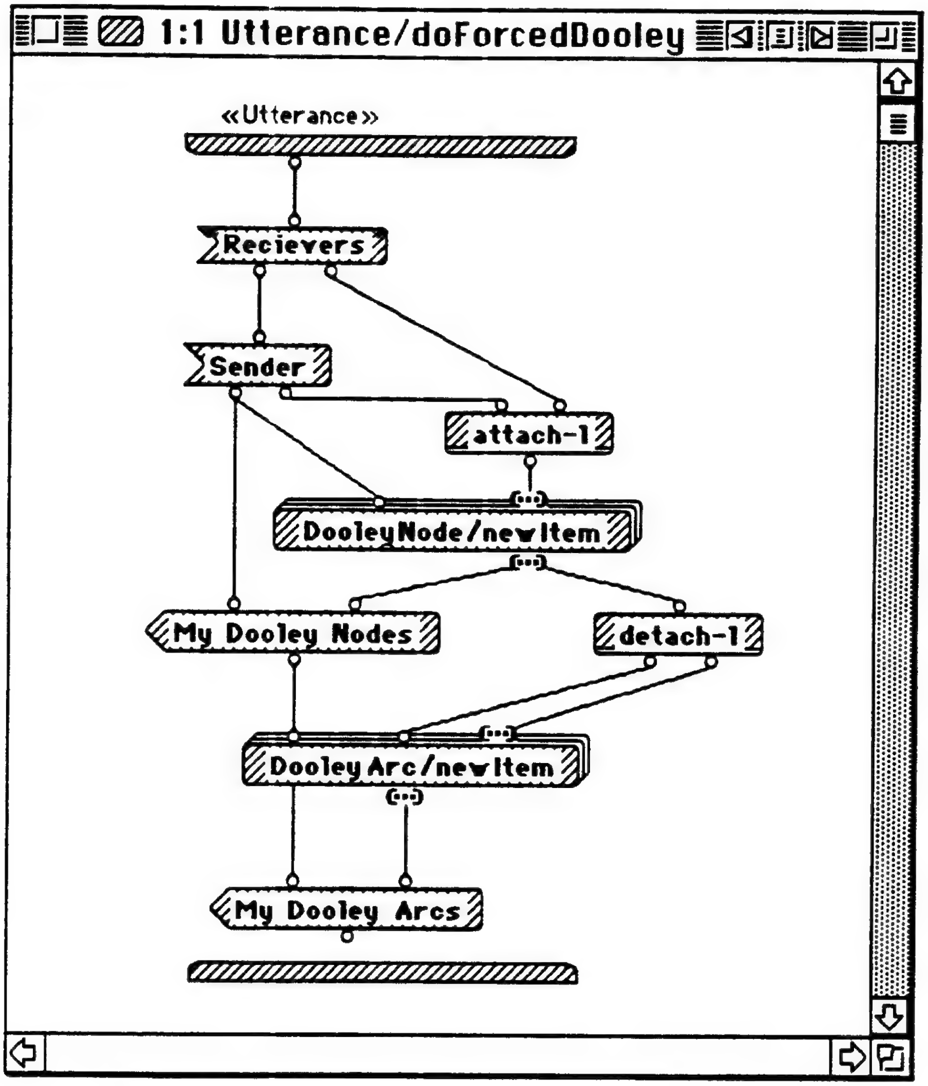

Figure 41-10:Method:Utterance/doForcedDooley

The other Utterances receive a */beginDooley* message. The utterance in turn checks to see if it resolves an utterance or completes an utterance. If it does nei-

ther it sends itself a message to */doDooley*. If it does resolve or complete an utterance it sends itself a */doOnlyArcs* message.

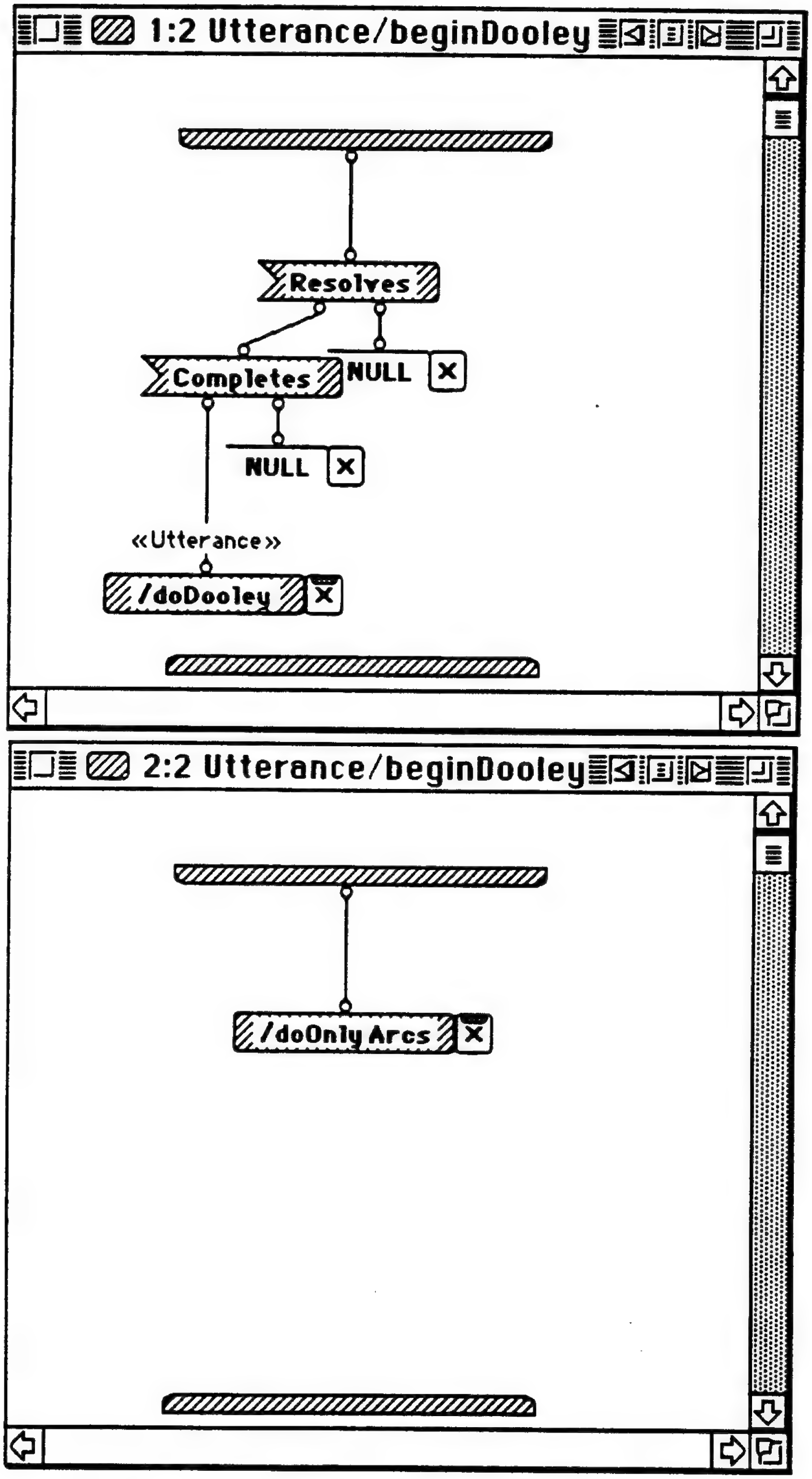

Figure 41-11:Method:Utterance/begin/Dooley

The */doDooley* method in the Utterance class creates nodes and arcs in similar fashion to */doForcedDooley*. As in the */doForcedDooley*, a set of DooleyNodes are created. In */doDooley* however, the list of DooleyNodes are based only on the set of receivers (Actors). The DooleyArcs are defined based on the set of DooleyNodes, but the Utterance object uses the *Replies To* utterance to obtain a related node. This related node is used as the *Sending* node when creating the list of Dooley arcs.

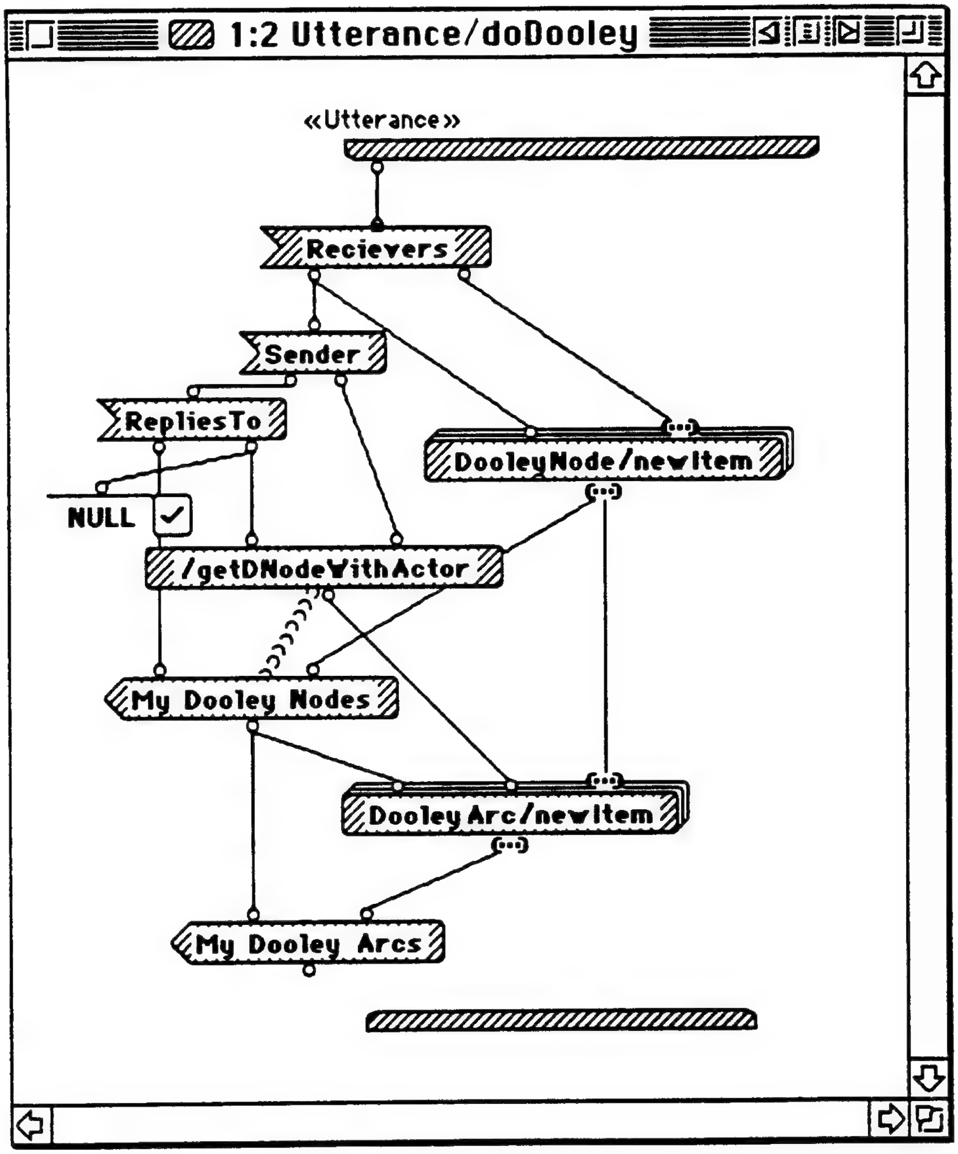

Figure 41-12:Method: Utterance/doDooley

The method *Utterance/doOnlyArcs* is called for non-spawning utterances. It basically relates existing nodes using Dooley arcs. The utterance queries the Replies

To utterance for a list of related nodes (using the Sender and list of Receiving actors as a basis), and creates DooleyArcs for each pair.

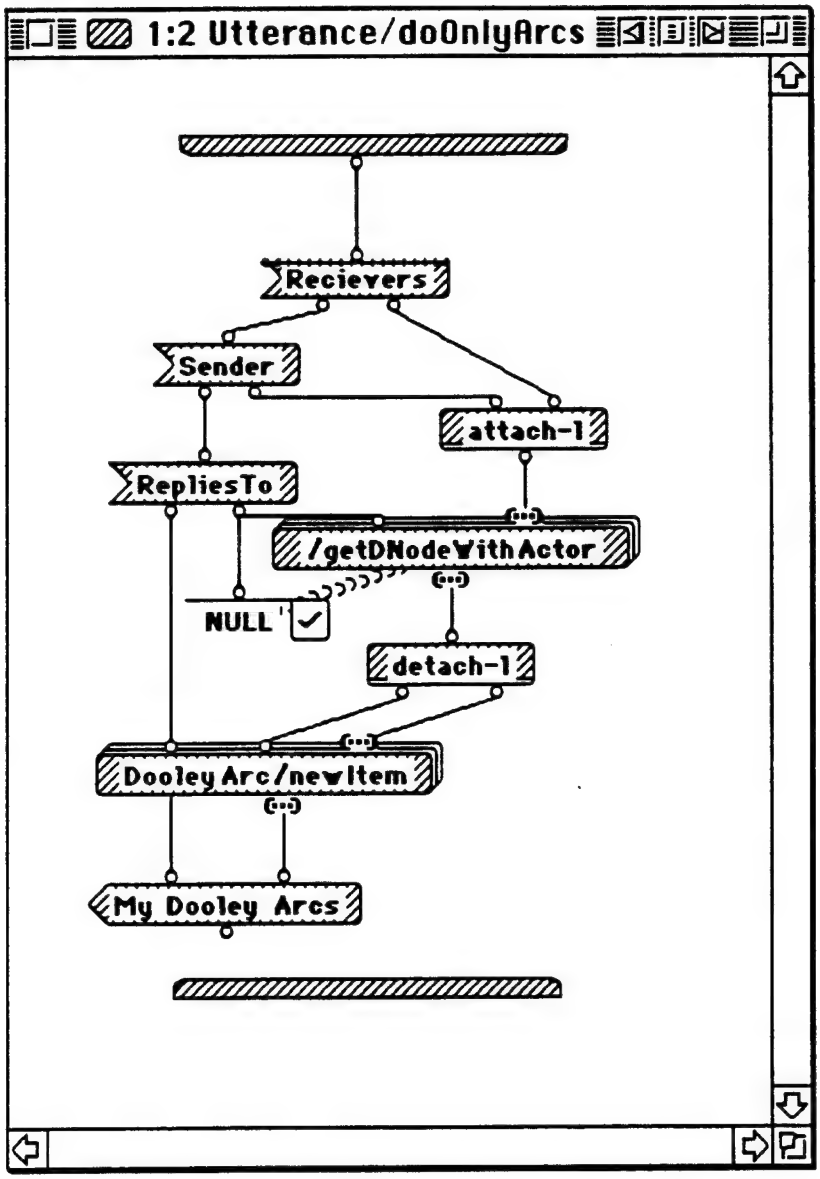

Figure 41-13:Method: Utterance/doOnlyArcs

41.6.7 Key Pomegranate Classes

[The class structure of the prototype.]

41.6.7.1 CLASS: Conversation Document

Subclass of: Document
Section: Agility Documents

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Purpose: Provide file I/O support. Contains and instance of Conversation.

Responsibilities: Save Conversation Document to disk. Load a Conversation Document from disk into memory. Provide dialog for user to define Conversation Document file name. Provide dialog for user to select a specific Conversation Document to open.

41.6.7.2 CLASS: Conversation

Base Class

Section: Agility Documents

Purpose: Provide container for actors, utterances and Dooley Graph objects. Manages calculation of Dooley Graph.

Responsibilities: Provide method to add an instance of actor. Provide method to add an instance of utterance. Provide a method to delete an utterance. Provide method to support calculation of Dooley Graph.

41.6.7.3 CLASS: Utterance

Base Class

Section: Agility Utterances

Purpose: Base class for Utterance. Provides definition of the sender of specific utterance, and the set of recipients of specific utterance.

Responsibilities: Record who is the sender of the utterance. Record who receives the utterance. Provide technique for creating Dooley Nodes based on the type of utterance.

- CLASS: Utterance SUBCLASS: URequest
  Section: Agility Utterances
  Purpose: Subclass of Utterance.
- CLASS: Utterance SUBCLASS: URefuse
  Section: Agility Utterances
  Purpose: Subclass of Utterance.
- CLASS: Utterance SUBCLASS: UPropose
  Section: Agility Utterances
  Purpose: Subclass of Utterance.
- CLASS: Utterance SUBCLASS: UShip
  Section: Agility Utterances
  Purpose: Subclass of Utterance.
- CLASS: Utterance SUBCLASS: UPay
  Section: Agility Utterances
  Purpose: Subclass of Utterance.
- CLASS: Utterance SUBCLASS: UAssert

8

Section: Agility Utterances
Purpose: Subclass of Utterance.
CLASS: Utterance SUBCLASS: UCommit
Section: Agility Utterances
Purpose: Subclass of Utterance.

41.6.7.4 CLASS: Actor

Section: Agility Utterances
Purpose: Provides the definition of a participant in a conversation.
Responsibilities: Capture name of participant in a conversation.

41.6.7.5 CLASS: Dooley Graph

Base Class
Section: Agility Utterances
Purpose: Contains Dooley Nodes and Dooley Arcs that result from the calculation of a Dooley Graph (the algorithm).
Responsibilities: Manage the generation of Dooley Nodes and Arcs at the time a request is made to perform the Dooley Calculation. Provide for the generation of display elements.

41.6.7.6 CLASS: Dooley Node

Base Class
Section: Agility Utterances
Purpose: Relates the Actor who *owns* the node and the Utterance that *creates* the node.
Responsibilities:

41.6.7.7 CLASS: Dooley Arc

Section: Agility Utterances
Purpose: Relates 2 Dooley Nodes (Source and Sink).

41.6.7.8 CLASS: Utterance Thread

Purpose: Experimental

41.6.7.9 CLASS: Conversation Window

Subclass of: Window

8

Section: Agility Windows

Purpose: Display the list of Actors, and the list of Utterance. Provides a means to add actors to the conversation and to add/subtract utterances to a conversation. Provides a means to open the utterance editor for a specific utterance. Provides a means to start the calculation of the Dooley Graph.

41.6.7.10 CLASS: Dooley Graph Window

Purpose: Displays the Dooley Graph.

Responsibilities: Provide a GUI container for elements that graphically represent a Dooley Graph of a Conversation. Provide methods for inspecting elements in the graph and moving elements.

41.6.7.11 CLASS: Dooley Bag

Purpose: A GUI element used in the Dooley Graph Window to represent a single Dooley node.

Responsibilities: Provide a user interface mechanism to notify container window of user interaction. Draw contents of Dooley Bag in owning window.

41.6.7.12 CLASS: Dooley Item

Purpose: Experimental

41.6.7.13 CLASS: Utterance Editor

Purpose: Provides a means to edit a single utterance. Can specify the sender of the utterance, the recipients of the utterance, and the type of utterance.

Responsibilities: Interact with a specified Utterance. Provide GUI elements to specify sender, recipients and type.

41.6.7.14 CLASS: Utterance Grid

Subclass of: GRID

Purpose: Displays Utterance Row objects.

41.6.7.15 CLASS: Utterance Row

Subclass of: ROW

Purpose: Predefined collection of window items organized such that each Utterance can display its information in the Conversation Window in the Utterance Grid. Each Utterance instance has a link to a Utterance Row instance. An utterance row displays summary information about each utterance - type, sender, recipients and a summary string.

41.7 Section/Class Cross Reference

[CPX programs are arranged by sections. Here is a class/section cross-reference.]

This section lists each CPX *section* that has been added to the typical baseline ABC Application. These sections or files contain the classes/methods/universals/ persistants that define the operation of Pomegranate.

41.7.1 Section: Agility Database

[Classes of the Agility Database section.]

Agility DB Manager
Agility DB Specifier
Enterprise Window

41.7.2 Section: Agility Documents

[Classes of the Agility Documents section.]

DooleyGraph Doc
Conversation Document
Conversation
Agility Project Document
Agility Project Data
Conversation File

41.7.3 Section: Agility Preferences

[Classes of the Agility Preferences section.]

AgilityPrefs000
Agility Prefs File
Agility Prefs Window
AgilityPrefs001

41.7.4 Section: Agility Utterances

[Classes of the Agility Utterances section.]

Actor
Utterance Thread
Utterance
URequest
URefuse
UPropose
UCommit

UAssert
UShip
UPay
DooleyArc
DooleyGraph
DooleyNode

41.7.5 Section: Agility Windows

[Classes of the Agility Windows section.]

Bag Layout
Utterance Grid
Utterance Row
Dooley Bag
Dooley Line
Conversation Window
Utterance Editor
Dooley Graph Window
Segue Agility
Actor Editor
Agility Project Window
Conversation File Row
Agility Window

41.7.6 Section: Agility Workspace

[Classes of the Agility Workspace section.]

AgilityMetricsMenu
EntepriseMenu
Pomegranate Edit Menu
Pomegranate File Menu
Apple Menu
Agility App
Help Menu
Scroll View Task
Agility RDF
Transform
Hilite Node Task

42 Dooley Graph Algorithm

[This section details the Dooley Graph algorithm]

Information in this section was provided by the Industrial Technology Institute:

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Fax: 313/769-4064

42.1 What is a Dooley Graph?

[The procedure is given here.]

Formally, a Dooley Graph is generated by a 4-tuple $<E, P, M, A>$, where

$E = \{1, 2, \ldots, n\}$ is a set of counting numbers indexing the chronologically ordered (or at least orderable) utterances in the conversation;

$P = \{p, p, \ldots, p\}$ is the set of participants in the conversation;

$A = \{<p, p, k>: <p, k> (S \;\&\; <k, p> (R\}$ is a set of ordered triples, defined with the aid of two sets of ordered pairs over E and P: the Sender set $S = \{<p, k>$: participant p sends utterance k$\}$, and the Addressee set $R = \{<k, p>$: participant p receives utterance k$\}$. (The notation *R* reflects Dooley's use of the word *recipient* rather than *Addressee*.) There is no assumption that each utterance has only one sender and one addressee. However, we do assume that there is no promiscuous eavesdropping. Each triple in A will become an arc in the Dooley Graph.

M is a relation from S(R to S(R, which generates the vertices of the graph and indicates which arcs (utterances) are linked at which vertices. It is subject to the restriction that whenever two ordered pairs are M-related, their P coordinates must be the same. That is, M may relate two utterances if either

- the two are sent by the same participant,
- the two are addressed to the same participant,
- the addressee of the first sends the second, or
- the addressee of the second sent the first.

M *may* relate two utterances under these conditions. Whether it actually does or not depends on the particular discourse theory that one wants to represent in M. M is the mechanism by which the vertices of the graph are defined. The *same participant* requirements above will ensure that each node in the graph corresponds to a single participant, while the restrictions imposed by the discourse theory keep all instances of a single participant from collapsing into a single vertex. Within the bounds of this restriction, we can expect to do considerable experimen-

tation with the actual definition of M to provide graphs with the right balance of state and participant information.

Dooley originally suggested the condition that <i,p>M<p,j> iff any of three conditions is met:

- j replies to i,
- i replies to and resolves j,
- i replies to j and is the last utterance in the conversation.

To capture the information in the *completes* relations between utterances, I add a fourth option:

- i completes k and k replies to and resolves j.

Thus completion becomes a way for utterances to inherit resolution from one another. This definition does not capture any information from the *resolves* relation.

[PARU96b] discusses why *resolves* is needed, shows why it difficult to capture it in the M relation, and suggests a solution that augments the basic Dooley Graph.

We move from <E, P, M, A> to a graph by the following steps.

- Define an equivalence relation N over S(R by first copying M into N, then closing N under symmetry, reflexivity, and transitivity. (If aNb, add bNa, aNa, and bNb. If aNb and bNc, add aNc. Repeat until there are no further additions to N.)
- N induces a partition V = (S(R)/N of S(R. The elements of V are the vertices of the graph. The P coordinates of all the members of any one element of V are the same (though there may be several vertices representing a given participant), and are labeled by their P coordinate and an appropriate index. The arcs of the graph are the triples in A. For $<p_i,p_j,k>$ (A, there exist unique members v., v of V that contain <p, k> and <p, k>, respectively, and an arc labeled k is drawn from v. to v.. Intuitively, a participant moves from one vertex to another when control of the conversation changes, that is, when another participant replies to a *solicit* with other than the *act* expected by the *solicit*, or otherwise initiates a new thread. Thus a conversation in which every participant knows its place and speaks only when spoken to appears as a graph with only one node per participant, while a free-for-all spawns long chains that represent participant's attempts to gain control of the conversation.

42.2 An Example

[An illustrative example is presented.]

As an illustration, we develop the Dooley Graph for the example conversation in Part 1.

Sequence	Sender	Receiver	Utterance	Speech Act	Responds to	Replies to	Resolves	Completes
1	A	B, D, C	Please send me 50 widgets at your catalog price by next Thursday	Request				
2	B	C	Are you bidding on A's RFQ?	Question	1			
3	C	B	Yes, I am	Inform	2	2	2	
4	B	A	I no bid	Refuse	3	1	1	
5	C	A	How about 40 widgets at catalog price by next Friday?	Inform, Request	1	1		
6	A	C	Please send me 40 widgets at catalog price by next Friday	Request	5	5	5	
7	C	A	I plan to send you 40 widgets at catalog price by next Friday	Commit	6	6	6	
8	D	A	I plan to send you 50 widgets at catalog price by next Thursday	Commit	1	1	1	
9	A	C	I've found a better supplier, and am not relying on your Commit	Assert	7,8	7		
10	C	A	I am abandoning my Commit	Refuse	9	9		7
11	D	A	Here are your widgets. Please pay me	Ship	1	1		8
12	A	D	You are five short. Please send the difference	Assert, Request	11	11		
13	D	A	Here are five more widgets, Please pay me.	Ship	12	12	12	
13	A	D	Here's your moola	Pay	13	13	13	

Table 42-1: Breakdown of an Example Process

By examination,

- E = {1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14}
- P = {A, B, C, D}
- A = {<A,B,1>, <A,C,1>, <A,D,1>, <B,C,2>, <C,B,3>, <B,A,4>, <C,A,5>,

<A,C,6>, <C,A,7>, <D,A,8>, <A,C,9>, <C,A,10>, <D,A,11>, <A,D,12>, <D,A,13>, <A,D,14>}

The construction of M is the least intuitive part of the process. To help clarify it, I will develop M in four parts, corresponding to the four eligibility conditions a-d outlined above for <i,p>M<p,j>. To simplify the notation, I write '1B' for the addressee pair <1,B>, 'B2' for the sender pair <B,2>, and similarly for other utterances and participants.

- j is a reply to i: M. = {<2C, C3>, <1B, B4>, <1C, C5>, <5A, A6>, <6C, C7>, <1D, D8>, <7A, A9>, <9C, C10>, <1D, D11>, <11A, A12>, <12D, D13>, <13A, A14>}
- i replies to and resolves j: M. = {<3B, B2>, <4A, A1>, <6C, C5>, <7A, A6>, <8A, A1>, <13A, A12>, <14D, D13>}
- i replies to j and is the last utterance in the conversation: M. = {<14D, D13>} (already included in M.).
- i completes k and k replies to and resolves j: M_e = {<10A, A6>, <11A, A1>}

The resulting partition of S(R is

- V = {A, A, B, B, C, C, C, D, D}, where
- A_1 = {4A, A1, 8A, 11A, A12, 13A, A14},
- A_2 = {5A, A6, 7A, A9, 10A},
- B_1 = {1B, B4},
- B_2 = {B2, 3B},
- C_1 = {1C, C5, 6C, C7},
- C_2 = {9C, C10},
- C_3 = {2C, C3}
- D_1 = {1D, D8, D11},
- D_2 = {12D, D13, 14D}.

The figure shows the resulting Dooley Graph. Several components of this graph invite discussion. I will label components by sets of vertices, and include by reference all edges among those vertices.

- The conversation originates in {A., B., C., D.} as A broadcasts a *request* to its trading partners B, C, and D. B and D respond as expected, resolving A's *request* with a *refuse* and a *commit* respectively, so their responses remain within the original component. Because D's original *ship* (utterance 11) completes its *commit* (utterance 8), the *ship* is also part of this component.
- C does not accept the terms of the discussion. Its *propose* (utterance 5) does not resolve A's original *request*, spawning a new component, {C., A.}, in which C and A agree on new terms, leading to a *commit* by C at utterance 7.
- A sidebar conversation between B and C before B's decision not to bid (utterances 2 and 3) generates a separate component of the graph (Nodes B. and C., utterances 2 and 3). This component is separate because none of its utterances replies to or completes any of those in the main component. We can integrate it

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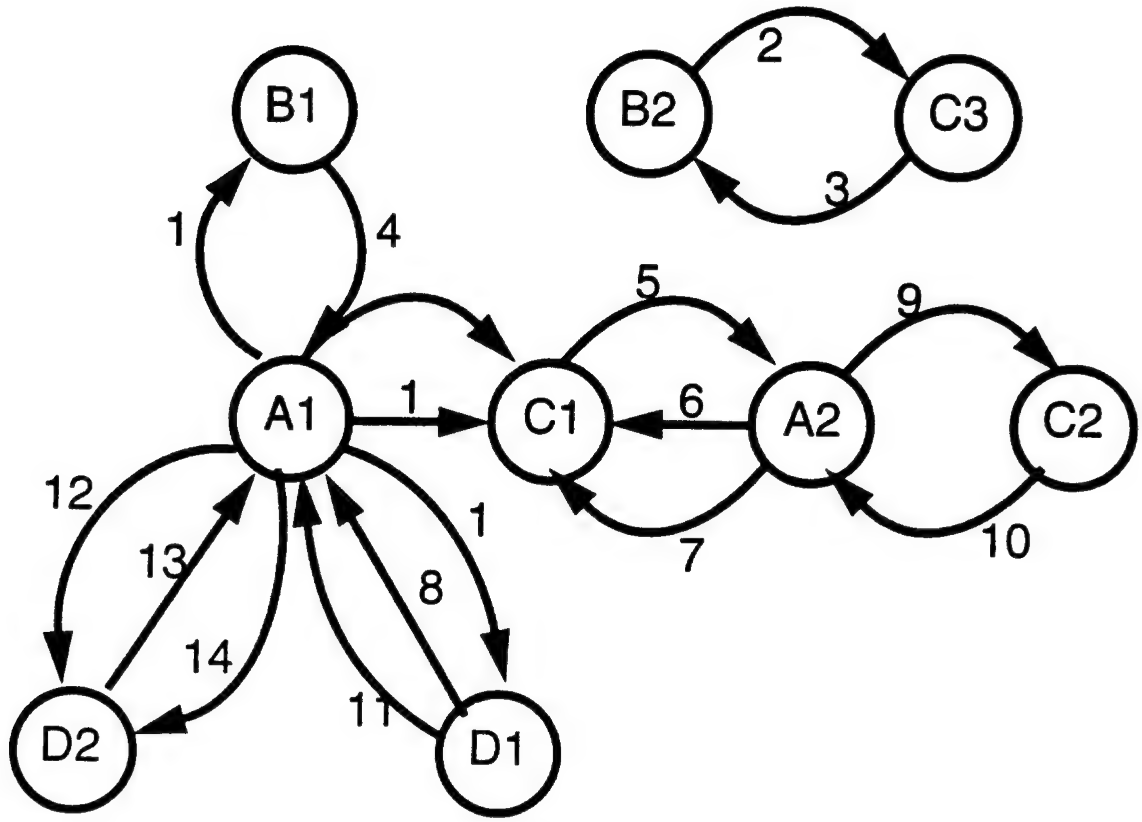

Figure 42-1:The Example's Dooley Graph

with the rest of the graph by using information from the *responds* relation, but there are trade-offs, discussed in the next section.

- The numbering of the utterances shows that D's *commit* (utterance 8) arrives after C's (utterance 7). Because D's *commit* matches A's original *request* while C's does not, A cancels the arrangement with C in utterance 9. This utterance does not resolve any utterances in {C, A}, and so initiates a new component, {A, C}, a topological reflection of the discontinuity that such a withdrawal represents in the overall conversation.
- A's conversation with D also spawns a new component, {A, D}, when A finds D's initial *ship* (utterance 11) deficient. Again, the topology of the graph captures the discontinuity in the expected course of the conversation.

Part 4, Tool Strategy

43 Turnip and the Topology Perspective

[We note that we have a proprietary approach which generalizes the metrics approach to other analytical and representational areas.]

Sirius-Beta has two core competencies. One is in broad interdisciplinary approaches to novel architectural problems dealing with enterprise infrastructure and emerging commercial enablers. The Metrics Project taxes this expertise, which has produced this report. But there is a related strength which relates to the Tool Strategy. It is the subject of this section.

Concerning the other strength, prior work has focused on a novel approach to conceptual indexing which is related to the method we used in devising the metrics. There, we characterize action using the conceptual types of performatives and work with a few simple topological characteristics (the complexity of the conversation, the process) to linearly (meaning quantitatively) index one of its characteristics (its ability to adapt).

In the more general approach, we can use a variety of characterizations, work with more complex topological characteristics, and index many characteristics multidimensionally. We'll just briefly note each of these, then suggest how the Tool Strategy is affected.

43.1 Federated Representations

[Syntactic abstraction, the form of the information, as a lever for federating diverse representations.]

Several studies have indicated the importance of *model federation*. This is the situation where diverse parties each have their own representation system (models, languages, ontologies...), have *control* over those representations, but can collaborate as if they all had the same representations. A presumption is that this is desirable, as in the case of the AVE, where great strengths in partnering often result from seeking a partner who radically differs from you.

We salute this goal and accommodate it in the metrics, but in a way that effectively avoids the problem. We can extract the performatives we need from many representational schemes, and substantial work has been done in this regard by knowledge sharing researchers. But our case study indicates that the cheapest route is simply to remodel the few processes of interest directly in the performatives, which in other contexts would be considered an intermediate form.

Two other agility projects more directly address the federation problem, taking different compromises. As we link with one or both of these, we will too.

In a manufacturing enterprise, the problem of federation is exacerbated by the necessity of some parts of the organization to control other parts with sensitivity to both an absolute and a state vision of time. Standards are not the answer, that just stamps out the diversity we want to encourage.

One answer appears to be metastandards. Instead of trying to get all the nations on the *Tower of Babel* project speaking the same language, better to have all those languages mapped to a common model. (Metastandards for languages need to be models, for models, languages.)

Good work toward this goal has been done by the *Semantic Unification Meta Model* [FULT92] standard-related effort. But even if that were extended to handle dynamics, there is a lot of work to be done in normalizing the target languages and registering each with the metamodel. The world is not so kind as to make this even remotely thinkable.

But what if the detailed semantics of the languages became less important. Suppose syntactic structure was emphasized? This is not a trick question. The semantic content of a statement is its *meaning*. The syntax merely how the meaning is packaged. It would seem only common sense that the syntax is unimportant. But consider a few cases:

- I have a dog who seems to understand all the important commands. He has no idea what the semantics of those commands are. It seems likely that he has learned a few words by sound, for instance his name. But what he picks up, he gets from the *way* I say things, including body language.

  Now, there are terrible arguments over whether this wrapper, my movements and voice inflections, constitute indirect or supplemental semantics. But they are in the category that *we* prefer to call syntactic.

- The intelligence community is interested in this kind of syntax. It may be more important that mobilization command messages are going from headquarters to the field than what the detailed contents of all the messages are. In fact, often such details are distracting from the most important meaning. The best example is that the roughly 2 trillion dollars spent on understanding the Soviet Union generated a great many details, but still missed predicting the event of the century, its sudden collapse.

  Syntactic abstraction looks at the form of information to get some meaning from it. Internet crooks already have excellent profiles to determine whether a message is an order that is likely to contain credit information. These kinds of profilers are in use (by others) to categorize all sorts of messages. It's the basis of vast indices.

- Imagine that we are not talking about military messages, but their components, *concepts*. If we can normalize these concepts into a single form, like we did handily with the performatives, we could index some features about their syntax.

But suppose that different forms exposed different features worthy of indexing, which means each concept would be mapped into a number of different forms. Also suppose that the sources weren't presented to you in a uniform format. In the intelligence domain, they could be messages in a different languages, human and machine. They could be unstructured parameters such as the number of tanks or grain yield at a certain place; or images; or parametric streams like financial transactions, and the semantics may not be available to you in any case because of encryption (which only really affects semantics).

Then you'd be mapping many source forms against many normalizing syntax representations. This is a real mess. That is, unless you had a viable metamodel for all normalizing representations. Then you might not have the dozens or hundreds

or millions of mappings (like the performatives) all prefabricated. You might instance them on the fly. In fact, you might not *really* instance them, instead just note how they might be instanced from the metamodel.

Moving from a representation to a useful categorizing abstraction of any sort is *type abstraction*, a fairly well understood discipline, something that is done all the time. But a reader might understand that what we've described is doable, but absolutely useless. We'd be taking things that are relatively simple, that probably relate in some intuitive way to the real world, and which have *meaning*. And we'd be replacing that with many, many (arbitrarily many *manys* here) representations that are less intuitive, less connected to the phenomena of interest. Why would we do such a thing? It's the computer science problem from hell.

The answer is:

- We get leverage on the federation problem. If we throw model needs into the leverage pot, we can federate into solution domains. We did this in our naive version of the process with the metrics, federating process models into parametric models.
- The amazing complexity of the method is manageable because we can express each type, each abstraction relationship, each metamodel and each metarelationship in the same simple language and deal with them all by applying functions wholesale, over patterns or clusters of them.

43.2 Categorical Types

[Some tricks to abstracting that enable the approach.]

There are a multitude of ways to define types and attitudes about what they represent. We simplify our type universe by:

- Insisting on *categorical types*. Category Theory [AL91] [CROL93] [MACL71]is a theory of typing *functions*. So by insisting on types as narrowly defined there, we end up with elements specifically designed for functional indexing. All we have to do is be moderately careful about the relationships between models and languages, and we're halfway toward concept indexing. Category Theory is especially useful in that one can recast formalisms in it normally based in set theory, the default for modelers and logicians. This means that we can see not only the types, but the language syntax from which these types were abstracted in categorical terms. Very important for the reflection noted below.
- Requiring that the functions have topology in the abstraction (the type) space. An example of a simple topology was the node/loop topology we leveraged in the Dooley Graphs. There the types were based on both the notion of state and performative to reveal the syntactical topology. We need the topological syntax for two reasons
  - We'll be typing (abstracting) from the types an arbitrary number of times. This means that there has to be *syntax*, abstractable representation structure, at both ends. This is guaranteed by limiting the types to

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topological abstractions.

♦We'll want to dive in at any point in our representation (or meta- or metametarepresentation) and use it for analysis. The analysis will be on syntax, of the same nature as our node/loop counting. In other words, we want to be able to vectorize any concept at any level of abstraction (a vector being just a linearization of a topological feature), and work with bundles and fibers (for instance) to give us concept clustering or pattern matching. This also is guaranteed by limiting the types to topological abstractions.

Note that our efforts with Situation Theory will bringing soft context into the same type structure as first class objects.

43.3 Symmetry Grammars

[A novel representation space based on group theory and topological features of syntax.]

We are faced with vast numbers of types, type fragments and abstraction statements, together with whatever administrative information is included. (This information is treated the same as all the rest which is to say it is both something *about* the system and a constituent *of* the system.) But we pulled a trick we didn't mention earlier. When constraining the type abstraction strategy to topological syntax, we constrain to certain *types* of topological features.

We use the device of a semantic network for interrelating features, as do many folks. (Of course we don't store the semantics of the concept, but a semantic representation of its syntax, as we've noted.) We constrain the structure of the nets to lattices, regular periodic lattices. Such structures have symmetries, as do the elements which *populate* it.

We exploit these symmetries by constraining the topological features we abstract to the symmetrical structures of the representation space. What we are faced with then is a vast amount of information which is expressed by location on a simple lattice (usually of high dimension). What it is can be described in simple statement using a few symmetry statements. What its relationship to any other element can be described in the same symmetry primitives.

Indeed, those primitives form a grammar of sorts that describe transforms, clusters, patterns, mappings, essentially anything you need to support analysis (by aggregation and abstraction) and presentation.

There is a cost to such an exotic representational framework. But since the overhead is constant as the complexity of its contents increase, it becomes increasingly cheaper as the situations become sufficiently complex to be real and useful.

We've spent substantial energy examining benefits of differing symmetries, differing dimensions and the useful transitions between them [LALV77] [LALV90]. Transforms among the lattice can both be coded in the lattice and affect the laws of the lattice.

But we haven't spent much time on analytical interfaces. Fortunately, group theory and symmetry are intrinsic to many disciplines and analytical approaches, both on the hard and soft sides. We believe that a promising approach linearizes the complexities of groups into graphs, and leverages well established techniques in the graph theoretical community [KAHL95]. These folks know how to deal simultaneously with terms and metaterms denoting types and metatypes in a normalized space.

43.4 A Powerful Extension of the Tool Strategy

[How this is reflected and exampled in Turnip.]

This all sounds exotic, and it is. It's a novel general conceptual federation, indexing and manipulation scheme for complex, dynamic situations. What might this mean for our present problem? Turnip is an example of how this might be put to use.

What we do in Turnip is the simplest case. The purpose is to interface to a large case base, such as the MIT Case Base, or a similar repository in a large consulting firm. We could federate to many diverse case pools. We index salient features of their processes; in the present case their systemic adaptability (agility) is what interests us.

We normalize those features into vectors and constrain the topology along dimensions defined by our internal agility metric. These become fiber bundles, whose characteristics and *density*, can be browsed by a planner. Where the density is high, it means that many concepts are clustered, that there are similarities.

Depending on what you've constrained, you could look for similar conditions or responses and they would show, shorn of distracting context. You'd then click on a column (the fiber bundle's Turnip representation) and go to the case base index, the Mashed Potatoes system tool or a Pomegranate-like (or ISTI or KBSI) process analysis tool.

All of the exotic topological dynamics are hidden from the user. We've spend some time at BAST studying the topology of Situation Theoretic statements. We believe that as we move forward in the soft mathematics agenda, these can be incorporated in the symmetry field.

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44 Integrating with Other Strategies

[We went far in arranging ways to coordinate with other projects. Here's how.]

44.1 The MIT Case Base

[They use the same type of performative basis we do. We believe their front end can incorporate our general evaluative approach.]

The MIT Case Base is being performed by two labs in MIT. The Sloan School part is parsing enterprises into process components and storing them in a database. Fortunately for us, this breakdown is being done using a *communicative act* (in their terms a collaborative act) breakdown. We believe that a mapping can readily be made between the projects so that:

- each stored process in the handbook can have an *intrinsic* agility metric applied to it, depending on context. MIT appears to believe that there are a finite, describable set of contexts. If this is so, the metrics can be stored with the process.
- Patterns of processes with predictable agility can be detected to generate a list of rules of thumb for specific uses.

The other part of the MIT project is being conducted by the Artificial Intelligence Lab; this part deals with facilitated user interfaces to the case base. Since we have been careful to build reflective capabilities into the method, we can support an evaluative a component in this part.

Reflection is the ability of a language or model to see and comprehend itself. It is important when you have something like information infrastructure which is used for dynamic replanning and response. When used in this dual mode, the infrastructure is both *part* of the enterprise in the sense that it is part of the control system, and *outside* of the enterprise in that it analysis it as a separate set of phenomena.

We plan on working with MIT as we examine the reflective effects of second order agility.

44.2 The ARRI Method

[We detail how our metrics can be incorporated above.]

The Automation and Robotics Research Institute of the University of Texas at Arlington hosts the NSF's Aerospace Agile Manufacturing Research Center. They have a method for enterprise engineering which is described above. We used them as a surrogate for the typical advanced consultant that we expect to find working in the defense aerospace community. Our metrics fold logically into their method. We believe this approach should work in the general case as a tool for agility that allows simultaneous evaluation of agility with other strategic factors.

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44.3 The ISTI and KBSI Agility Modeling Workbenches

[The KBSI link is based on Situation Theory, with ISTI some collaborative planning meetings.]

The agility initiative funds two complementary modeling projects by Intelligent Systems Technology and Knowledge Based Systems. The KBSI workbench is deliberately based on the conventional, ontological use of Situation Theory. We feel confident that BAST2 will provide a strategy for subsetting our logical statements so that all actons are expressible in pure infon terms. This will allow us to readily communicate with the KBSI tool as a plugin.

The ISTI tool is interesting, since it is being built from scratch for federation of different systems and in a federated way. The tool is object oriented. There is no major architectural feature that makes our tools congruent, but we have met several times at their lab and have a strategy for integrating Pomegranate as a plugin tool for customers who wish it.

44.4 The WTI Effort

[The focus here is on the BAST results.]

The Work and Technology Institute has been working the union of social/cultural issues with manufacturing technology and performance. Within the selection of sponsored agility projects they are the *soft* experts. We've conducted two workshops at their site, and they have been active participants in BAST.

We think that they will be using Rosenberg's Layering/Zooming approach [DR96] regardless of any collaboration with us. This makes it quite easy to interface with the family of tools that have Situation Theoretic expression.

44.5 The Autonomous Agent Project

[The performative breakdown can provide for intimate integration.]

One of the more novel agility projects advances the technique of using emergent, self-organizing behavior of autonomous agents to control elements of the AVE. This has a long way to go, but it is a potentially revolutionary approach. The partner on this project which is looking at foundations for a larger scope is the Industrial Technology Institute (ITI).

We've worked very hard to be able to merge with this approach when tools emerge. ITI was the partner on the team which specified the performatives and indicated the use of the Dooley Graph.

Moreover, since our advanced phase concerns the use of actions (agent-based actons) we involved ITI in BAST. Indeed, ITI facilitate BAST96. We feel confident that the way is clear for future collaboration that involves the future of their performative-based agent work, our Situation Theoretic soft modeling, and the metrics.

44.6 The AIMS Software

[Lockheed uses and agent-based performative system, as do we.]

Agile Infrastructure for Manufacturing Systems (AIMS) is an ambitious project led by Lockheed Martin, which we expect to lead to commercial software. The cen-

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tral component of the collaboration software, MECE, is evolved from DARPA sponsored work on collaboration which in turn depends on DARPA knowledge sharing work.

This work is based on speech performatives, as are the metrics. Our breakdown of acts is more sparse than that used by MECE, which is good news. We should be able to easily interface our reflective metrics to their internal breakdown of process performatives.

44.7 Commercial Federation Strategies

[Describes the new notion of Design Patterns, why we wanted to use them, and why we decided not to.]

We originally wanted to cast the implementation of the metrics in the form of *software patterns*. We felt that this would be the fastest way of communicating an implementation strategy for widespread use. (We describe patterns below.) This is the only element of the project that fell short of expectations.

Instead, we ended up implementing an example prototype, Pomegranate, to describe and demonstrate the class structure. In interviewing potential tool implementors, this was considered substantially more useful, even though substantially more effort was required to create a working prototype.

44.7.1 Background of Patterns

[What Design Patterns are.]

In the seventies, Christopher Alexander developed a theory of patterns for solving design problems in architecture [ALEX71] [AIS77] [ALEX79]. To quote his definition:

> "Each pattern describes a problem which occurs over and over again in our environment and then describes the core of the solution to that problem in such a way that you can use this solution a million times over, without ever doing it the same way twice."

While popular in architecture schools, the approach never caught on in practice. There is a similarity between this domain and software for business:

- There is a distinct division among the three major communities: those who design the buildings (or business tools); those who construct the environment (or build/manage the enterprise); and those who use the environment (or conduct business).
- There is a notion of *style* among designers which doesn't result in apparent user benefits
- The users in fact are quite ordinary people with very superficial insight (in most cases) into details of the system
- The results permeate life, concerning much of the daily activity of essentially all people.

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These similarities were not lost on the software community who found Alexander's ideas applicable to software design, especially in object oriented situations. The idea has become enormously popular in the object oriented community, spawning numerous books [CS95] [GHJV95] [PREE94] papers and conferences.

Probably the idea became popular in response to less formal ideas of component architecture emanating from Microsoft which aren't scalable to the enterprise.

44.7.2 Gang of Four Pattern Template

[How patterns are expected to be expressed.]

The dominant champions of patterns in the software domain are Erich Gamma, Richard Helm, Ralph Johnson and John Vlissides [GHJV95], otherwise known as the *Gang of Four*. They have developed a standard template for defining a design pattern. This template was what we hoped to populate in our description of implementations for the metrics:

44.7.2.1 Pattern Name (Scope, Purpose)

The pattern's name conveys the essence of the pattern succinctly. A good name is vital, because it will become part of your design vocabulary.

44.7.2.2 Intent

A short statement that answers the following questions: What does the design pattern do? What is its rationale and intent? What particular design issue or problem does it address?

- Also Known As

Other well-known names for the pattern, if any.

44.7.2.3 Motivation

A scenario that illustrates a design problem and how the class and object structures in the pattern solve the problem. The scenario will help you understand the more abstract description of the pattern that follows.

44.7.2.4 Applicability

- What are the situations in which the design pattern can be applied? What are examples of poor designs that the pattern can address? How can you recognize these situations?
- An applicable situation

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44.7.2.5 Structure: Participants

The classes and/or objects participating in the design pattern and their responsibilities.

44.7.2.6 Structure: Participant Name

Responsibility for what

44.7.2.7 Structure: Collaborations

How the participants collaborate to carry out their responsibilities.
[Collaboration]

44.7.2.8 Structure: Consequences

How does the pattern support its objectives? What are the trade-offs and results of using the pattern? What aspect of system structure does it let you vary independently?

44.7.2.9 1. A consequence bullet. Description of consequence

- Implementation
  What pitfalls, hints, or techniques should you be aware of when implementing the pattern? Are there language-specific issues?

44.7.2.10 1. An implementation Bullet. Description of Bullet

- Sample Code and Usage
  Code fragments that illustrate how you might implement the pattern in C++ or Smalltalk.
- Program Listing
  Known Uses
  Examples of the pattern found in real systems. We include at least two examples from different domains.
- Related Patterns
  What design patterns are closely related to this one? What are the important differences? With which other patterns should this one be used?
- Owner
  Your Name (yourname@host.domain). Last updated on Today's Date

44.7.3 Why We Passed

[We decided it wasn't appropriate.]

Part 4, Tool Strategy

We very much wanted to express our results in this way; it would have continued the philosophy of the rest of the work: to *do it right*. It would have continued in the vein of taking the most rigorous approach that supports users.

Our problem was that the pattern definition depends on a single, unambiguous definition of the *use* that is being addressed. We know that the metrics support agility, a concept that is context dependent. So not only do we have a variety of users, we have the awkward situation of the problem itself being dynamic.

Current patterns assume a static context. Dylan, a new object oriented language, was designed with the intent of being able to move object approaches into the dynamic environment. The project worked to raise the issue to the pattern and language communities, and a notions of *metapattern*, *dynamic pattern*, and *functional pattern* have been proposed.

But progress has been slow and fraught with problems. Results did not emerge in time for us to use. So we have carried this work forward into the followon tool strategy,

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